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CONDITIONING
WHEAT
for
MILLING

A SURVEY OF THE LITERATURE

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CONDITIONING
WHEAT
for
MILLING

A SURVEY OF THE LITERATURE

BY

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Washington, D.C. May 1960

PREFACE

The Northern Utilization Research and Development Division, Peoria, Ill., under the administration of the Agricultural Research Service of the U. S. Department of Agriculture, is one of the four large research laboratories established by the Department under the authority of the Agricultural Adjustment Act of 1938. At its inception this laboratory was called the Northern Regional Research Laboratory.

The function of the several regional laboratories is to conduct chemical, chemical engineering, and other scientific investigations on new and broader uses of farm commodities and on the products thereof. The commodities being investigated in the Northern Division are wheat, corn, and other cereal crops; soybeans and other oilseed crops (excepting cottonseed and peanuts); and new industrial crops.

The improvement of existing processes and the development of new processes for the increased industrial utilization of wheat and wheat products are among investigations of the Cereal Crops Laboratory of the Northern Division under whose auspices this work was undertaken. It is hoped that the data presented here will provide a basis for experimental work leading to improved milling practices and the production of flour of improved quality.

Acknowledgments: The authors are deeply indebted to the many companies, institutions, and individuals who have helped in this work by supplying lists of references, photostats of articles, and translations from foreign languages. The continued interest and generous aid of members of the Technical Committee, Association of Operative Millers, and of individual members of the American Association of Cereal Chemists materially furthered completion of the work.

The authors also sincerely thank those at the laboratory, for the many hours which they have spent in expediting this publication.

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CONDITIONING WHEAT FOR MILLING

A Survey of the Literature

NEED FOR THIS SURVEY

Wheat is "conditioned" before milling primarily to improve its physical state but sometimes to improve the baking quality of the resulting flour. American millers have recently shown much interest in conditioning methods. Since hot conditioning methods used in European countries reportedly shorten the time required for conditioning as well as improve the baking quality of weak wheats, the Technical Committee of the Association of Operative Millers recommended a thorough survey of world literature on the subject of wheat conditioning. This bibliography on conditioning of wheat includes articles on such related topics as hygroscopicity, thermal properties, and absorption of water by the wheat kernel. The survey is intended to provide the United States flour milling industry with information fundamental to the development of new and improved methods for the production of flour for industrial and food uses.

Experimental data found in the literature covered have been assembled and summarized in Part I. For the most part, opinions based only on general milling experience have not been included. Many published reports of experiments fail to give all the information necessary for a complete understanding of the work and evaluation of conditioning effects. Results of one experimenter can seldom be compared with those of another, because almost invariably the workers used different samples of wheat and their own individual methods of conditioning. Even results obtained by the usual tests for the quality of gluten and of baked goods are influenced by slight variations in the techniques of different individuals.

An effort was made to present experimental data (whether it was given originally in the form of a graph, a list, or a table) in such a way that the experimenter's results were reported accurately and the reader could make his own interpretation. The material was kept as much as possible in the form given by the author, although some rearrangements were necessary for clarity and for compliance with the style of this publication.

Many informative articles on conditioning (concerned with such phases as history, purposes, equipment, theory, and current practices) have not been mentioned in the summary, because they did not contribute to the experimental data. Attention is called to several articles in which brief accounts of the different methods used in conditioning and statements concerning their advantages and disadvantages are given: Altrogge (22),[1] Cleve (131), and Anonymous (12). A review of present conditioning practices in the United States, England, Australia, Canada, South America, and Continental Europe may be found in an article by Atkinson (43).

Literature on certain topics closely related to conditioning was reviewed to some extent, because the data presented supply information basic to an understanding of the changes that occur in the wheat kernel during conditioning. Such subjects as hygroscopicity and thermal properties of wheat and absorption of water by wheat are reviewed in Part II.

Compilation of the bibliography (Part III) was handicapped by the fact that many articles on conditioning were published in foreign or trade periodicals that are not covered by abstracting journals. It is hoped that an approximately complete bibliography for the years 1927-57 has been made from references generously supplied by companies, institutions, and individuals, from authors' literature citations, and through consultation of the following sources:

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[1] Underlined numbers in parentheses refer to Bibliography, Part III, page 103.

Bibliography of Agriculture	1942-57
Biological Abstracts	1927-57
British Chemical Abstracts, B.	1937-53
Chemical Abstracts	1927-57
Chemisches Zentralblatt	1927-33
Chemisches Zentralblatt	1943-44
American Miller	1939-57
Northwestern Miller, Index only	1926-42
Milling Production Section	1943-57
Die Mühle	1931-33
Die Mühle	1951-55
Die Mühle	July 1956-57

A few books or articles published before 1927 and after 1957 have been included in the bibliography. No attempt was made to list all articles that described patents, although some have been cited. Generally speaking, articles that described apparatus were not included, unless they also considered methods of conditioning.

PART I.--SUMMARY OF DATA IN THE LITERATURE ON CONDITIONING WHEAT

The preparation of wheat for flour production involves a number of procedures designed to put the wheat in the best physical condition for milling and to improve, if possible, its baking properties. Although it might be considered as part of the "conditioning" process, the cleaning of wheat will not be reviewed here. Washing has been considered only from the standpoint of the addition of water to the wheat.

The chief factors affecting good physical condition of wheat for milling are proper amount and distribution of moisture within the kernel. It may be necessary to extract or to add water, depending on the character of the wheat. Absorption of water is affected by time and temperature of the conditioning process. Time and temperature are also primary factors in conditioning wheat for improvement of baking quality.

DEFINITIONS

Types of Conditioning

In this literature summary on conditioning wheat the various procedures that have been used are grouped more or less arbitrarily according to the temperature employed.

Cold conditioning or tempering is the adjustment of moisture in the grain without the addition of heat.

Warm conditioning is limited to the adjustment of moisture levels in the wheat to the desired percentage with the use of heat at grain temperatures not exceeding 46° C. (115° F.), a temperature generally conceded to cause no appreciable chemical change in the grain. Soft wheats often need to be dried, whereas hard wheats require the addition of water.

Hot conditioning is the adjustment of moisture levels with the use of heat at grain temperatures in excess of 46° C. In Europe, high temperatures are frequently used to improve the baking quality of wheats with weak, overextensible gluten.

Special methods used in warm or hot conditioning are discussed separately rather than under the general headings. Such special methods include direct steam addition, vacuum conditioning, infrared heating, and some others that have only been tried experimentally.

European Methods for Evaluating Results

Various methods of conditioning, especially hot conditioning, have often been evaluated by their effect on dough properties and gluten characteristics. The use of the Farinograph,[2] Extensigraph, Mixograph, and Alveograph for the determination of dough properties and the wheat-meal fermentation time test for gluten (29) are widely known. Some gluten quality tests that are less well known in America are described below. It is apparent from the literature that there are minor variations in methods. For the most part, the following descriptions have been taken from Eckhardt (176, pp. 48-60), although additional references are cited.

Tests for gluten quality

The gluten swelling test of Berliner and Koopmann (69, 75, 83, 357, 423) measures the swelling in N/50 lactic acid solution at 27° C. of specially prepared gluten washed from meal or flour. The results, usually read after 2.5 hours, are given as Q_o or Q_n; the Q_o value (often referred to as the specific swelling number) is obtained for gluten washed at once from the dough, the Q_n value for gluten from dough that has stood for n minutes (usually 30). A modification of this method is based on a photometric determination of the turbidity developed in the N/50 lactic acid solution after certain holding periods under specific conditions. These determinations are converted to figures comparable to those given by the first method. The swelling number Q_0 increases as the stability of the gluten increases. Q_{30} increases as proteolytic gluten degradation decreases. In general, the following types of wheat have the indicated range of Q_0 numbers:

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[2] The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

	Q_0 number
German winter wheat	2-10
German spring wheat	10-12
Manitoba; northern spring and hard winter wheats	10-25
Durum wheat	2-10

The increase of Q_0 through heat treatment of a weak wheat is usually accompanied by a drop in the extensibility number because the gluten becomes shorter.

The gluten rest period test (Abstehprobe) of Berliner (75) has been described as a simplified but less exact swelling test. One gram of wet gluten is allowed to stand in 2-percent salt solution for a number of hours--the time is varied according to the temperature of incubation. The properties of the gluten are then determined by hand manipulation and ranked by the following rest-period-number scale:

1. Completely dispersed ("Leimkleber").[3]
2. Infinitely extensible and very soft.
3. Very extensible, slack, and weakly elastic.
4. Somewhat extensible.
5. Good properties; viscous, normally extensible and elastic.

For the Kosmin-Kranz extensibility test (372, 423) 1 gram of especially prepared wet gluten is made into a ball and suspended from a hook in a glass tube about 30 cm. long which is filled with a 2-percent salt solution. A 2-gram weight is attached to the dough ball. The entire testing apparatus is kept at 27° C. Two hours after an initial reading, the extension of the gluten is recorded in millimeters or centimeters as the extensibility number (Dehnzahl). Glutens can be divided according to their behavior in this test into the following five groups:

1. Elastic, inextensible gluten which keeps its original form.
2. Very extensible, only slightly elastic gluten which reaches the bottom of the tube in a short time.
3. Extensible, elastic gluten which stretches about 150 mm. in 2 hours.
4. Shorter, less extensible, inelastic gluten which breaks after a moderate extension.
5. Gluten which stretches somewhat but soon breaks.

Gluten of Manitoba wheat generally falls into the first group; that of good German domestic wheat may be in the third group.

Tests for baking quality

A few of the terms used in recording results of baking tests need explanation. The flour types referred to in German literature since 1934 are based on ash content; e.g., Type 812 has an ash content of 0.812 percent. Ranges in ash content permitted for various flour types in recent years are given in Newmann and Pelshenke (464, p. 290).

The following definitions are based on their descriptions.

Dough yield is the weight of dough obtained per 100 grams of flour when water has been added to give a standard dough consistency.

Bread yield is the weight of bread obtained, expressed as a percentage of a given amount of flour.

Volume yield is the loaf volume obtained from a unit weight of flour. The standard volume obtainable from 100 grams of air-dry flour is 400 cc.

The baking number of a flour, as evaluated by Neumann, equals the volume factor times the pore factor divided by 100. The volume factor is obtained as follows: Find the difference between the maximum loaf volume obtained from 100 grams of air-dry flour and 400. Subtract this difference from 100 if the loaf volume is less than 100. Add one-half of this difference to 100 if the loaf volume is more than 400. The pore factor is obtained from the scale:

Pore No. (Mohs)	Pore factor	Pore No. (Mohs)	Pore factor
7-8	95	6	80
7	90	5-6	75
6-7	85	5	70

The Mohs pore number is an arbitrary scale established by Mohs (443). The cut surface of a loaf of bread is blacked with a paste of lampblack and oil and pressed against a sheet of unsized paper in the manner of using a rubber stamp. The impression thus obtained is compared with a standard set of impressions scaled from 1 (coarsest and least uniform) to 10 (finest and most uniform) in crumb texture.

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[3] A kind of gluten, flowy by nature, that is found in wheat kernels that have been pierced by an insect.

COLD CONDITIONING OF WHEAT

Conditioning Without the Addition of Heat

Research on cold conditioning has been concerned primarily with the effects of tempering moisture and/or time on the ease of milling and on the yield and quality of the milled products.

Effect of moisture in wheat on moisture in mill products

Shollenberger (591) investigated the relationship between moisture in wheat and in the mill products. Data from three mills showed that the amount of water added to the wheat in tempering did not affect the amount of moisture present in the flour (table 1). Shollenberger accounted for this effect by the failure of most of the tempering water to penetrate into the endosperm. From table 1 it can be seen that the bran contained a distinctly higher percentage of water than did the other mill products.

TABLE 1.--*Moisture content of wheat and of mill products from three large mills*

Wheat or mill sample	Moisture content		
	Mill 1	Mill 2	Mill 3
	Hard red winter	Hard red winter	Soft red winter
	Percent	*Percent*	*Percent*
Wheat before cleaning and tempering------	12.40	13.90	14.04
Wheat after cleaning and tempering------	16.00	13.80	14.67
Mill products:			
Patent flour-------	12.12	12.97	13.32
Clear flour--------	12.88	13.01	[1] 13.22
Low-grade flour----	12.30	12.39	---
Red dog------------	---	11.70	---
White shorts-------	[2] 10.40	---	[2] 11.41
Brown shorts-------	13.28	[3] 12.28	12.15
Bran---------------	14.24	13.95	14.19

[1] Includes low-grade flour.
[2] Includes red dog.
[3] Includes white shorts.

Source: Shollenberger (591, table II, parts 1, 4).

Shollenberger (592) later studied experimentally the influence of relative humidity of the air in the mill and moisture content of the wheat on milling yields and moisture content of the flour. Hard wheats from various parts of the United States were used. Their moisture content ranged from 9 to 12.9 percent. All samples were tempered to 15 percent of moisture and were held from 18 to 22 hours before milling. Humidities ranged from less than 30 to over 70 percent. In discussing the results which he presented graphically, Shollenberger concluded, "Compared with the weight of the wheat before tempering, the samples containing from 9 to 9.9 percent moisture showed a net gain in weight of total mill products for all relative humidities given, while the samples containing from 12 to 12.9 percent moisture before tempering showed a net loss in weight of total mill products except for relative humidities higher than 60 to 69 percent." For each decrease of 1 percent in the moisture content of the wheat before tempering there was an increase of 0.6 percent in the yield of products. With each 10-percent increase in relative humidity above 35 percent there was an average increase of about 0.5 percent in the total weight of mill products. As in his earlier work Shollenberger (591, 592) found practically no relation between the amount of tempering water added to the wheat and the moisture content of the flour.

Tempering time

Stark (608) investigated the effects of five tempering times on the milling of Kansas hard wheat of 10.5- to 11.0-percent moisture content during early August of 1925. Data from the tests are given in table 2. While all tests showed a deficiency of moisture in the flour, milling at higher moisture levels would have been difficult because of high humidity and temperatures prevailing at the time of the study. Differences resulting from the various tempering periods were slight, but the 30-hour period was selected as the optimum. With

TABLE 2.--*Effect of tempering time on milling of Kansas hard wheat*

Conditions and characteristics studied	Tempering time of--				
	12 hours	18 hours	24 hours	30 hours	54 hours
Temperature of wheat at rolls------------------°F.--	89	88	90	87	84
Moisture at rolls---percent--	14.6	15.0	14.8	15.0	15.0
Moisture in 100% flour-do----	11.60	12.36	12.29	12.56	13.08
Ash, 13.5% basis-------do----	.411	.415	.414	.416	.408
Protein, 13.5% basis---do----	10.90	11.07	11.17	11.17	10.81
Absorption, 13.5% basis------	61.5	61.9	61.7	62.1	62.3
Volume--------------cu. in.--	170	170	169	171	166
Moisture in bran----percent--	12.18	13.34	13.14	13.52	13.20
Moisture in shorts-----do----	11.40	12.50	12.00	12.68	12.60
Yield-----------------------	4.26	4.30	4.30	4.30	4.28
Temperature in mill-----°F.--	89	88	86	83	82
Humidity in mill----percent--	70	73	68	68	75
Milling condition------------	Too dry	Sl.	Sl.	---	---

Source: Stark (608).

cooler weather a reduction to 24 hours was made with good results.

Swanson reported the results of a number of studies of the effects of tempering on the milling properties of wheat. In one study with Pence (626), Swanson reported the effects of tempering time on the distribution of sieve fractions from milling the Turkey variety of wheat that had been tempered to 16.75 percent moisture content as determined by the 130° C. oven test for 75 minutes. This moisture content corresponds with 15.5 percent moisture as determined on whole grain by the Brown-Duvel test. Grain was cleaned, scoured, and then tempered at three temperatures and for six periods of time. Two passes were made through experimental rolls equivalent to first and third breaks. The stock was then sifted with 24 wire and 50 and 70 grit gauze (G.G.) sieves. The results, expressed as grams of each fraction with an accounting for the 500 grams milled per sample, are given in table 3. Mechanical and evaporative losses contributed to the loss figure. Temperature and humidity of the room during milling were not controlled but were recorded. Moisture percentages for the sieve fractions were also determined. Branny stocks (over 24W) were in all cases higher in moisture content than were the other fractions. No consistent effects of length of tempering period on moisture distribution were apparent.

Swanson (615) also reported conclusions from somewhat similar studies on an Allis experimental mill and on a long system mill. The unpublished master's thesis by McCormick (408), whose research was supervised by Swanson, gives a detailed account of what appears to be these particular studies. Lots of wheat were tempered to 15-percent moisture content but held for different lengths of time (3 to 96 hours). They were milled at constant temperature and humidity. Swanson stated that essentially similar results were obtained with the two mills. He based his conclusions on data from experiments on the long system mill. Although McCormick noted that a considerable sampling error was evident, data on break flour production (table 4) compiled from his tables support Swanson's conclusions that low amounts of break flour were produced from the shorter tempering periods and the most break flour, from the medium tempering periods. The drop in break flour production after a 96-hour tempering period was attributed to unavoidable moisture losses from the wheat. The length of tempering did not affect the amount of middlings released from the breaks, the ash content of break flours, or power consumption. In connection with power consumption, data from a commercial mill (Stark, 608) are of interest: For tempering periods of 48, 72, and 84 hours, the respective power consumption was 6.5, 5.36, and 4.99 kilowatt hours per barrel. Stark noted that advantages in power savings from the longer tempering periods may be

TABLE 3.--*Sieve fractions obtained from grinding 500-gram samples of Turkey variety wheat*

Time of tempering, hours	Temperature of tempering	Temperature of room	Relative humidity	Sieve fractions--					
				Over 24W	Over 50 G.G.	Over 70 G.G.	Through 70 G.G.	Sum	Loss
	°F.	*°F.*	*Percent*						
1-----------	40	63	64	250.1	156.3	48.8	44.3	499.5	0.5
2-----------	40	64	56	243.4	157.8	50.6	47.2	498.5	1.1
4-----------	40	64	56	241.0	158.7	51.6	49.6	500.9	.9 gain
8-----------	40	61	63	233.5	158.8	53.2	52.1	497.6	2.4
16----------	40	58	66	222.4	165.6	56.7	55.7	500.0	0
24----------	40	57	67	218.8	163.2	57.3	58.3	497.6	2.4
Mean------		61	62	234.9	160.1	53.0	51.2	499	1.0
1-----------	64	66	61	226.6	159.9	54.8	53.5	494.8	5.2
2-----------	64	64	56	230.6	159.5	54.8	53.9	498.8	1.2
4-----------	64	64	60	227.2	158.1	53.4	57.2	495.9	4.1
8-----------	64	64	60	228.2	153.3	57.8	58.0	497.3	2.7
16----------	64	63	60	219.9	158.0	58.7	60.0	496.3	3.7
24----------	64	64	56	227.7	153.9	58.1	58.3	498.0	2.0
Mean------		64	59	226.7	157.1	56.3	56.8	496.9	3.1
1-----------	104	63	60	220.3	150.7	58.5	61.1	490.7	9.3
2-----------	104	61	63	220.5	142.5	62.8	66.8	492.6	7.4
4-----------	104	61	63	224.6	140.3	62.8	66.8	494.5	5.5
8-----------	104	62	64	229.7	133.4	62.0	66.8	491.8	8.1
16----------	104	58	66	224.2	155.9	58.0	57.8	495.3	4.7
24----------	104	59	67	220.0	155.6	60.4	59.9	495.9	4.1
Mean------		61	64	223.2	146.4	60.75	63.2	493.5	6.5

Source: Swanson and Pence (626, p. 436, table V).

TABLE 4.--*Break flour from milling 10-bushel lots of hard red winter wheat after various tempering periods*

Run[1]	Break flour after tempering for--						
	3 hours	6 hours	12 hours	24 hours	48 hours	72 hours	96 hours
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1a-----	0.57	0.56	0.87	0.88	1.10	1.50	0.51
1b-----	.60	.58	.57	.53	.86	1.10	.6
2a-----	1.0	2.1	1.6	2.0	2.7	2.0	2.0
2b-----	1.8	1.9	1.8	2.2	2.5	1.7	2.3
3a-----	1.5	1.1	1.8	1.7	1.2	2.1	1.5
3b-----	1.5	1.2	1.6	1.2	1.5	2.1	1.3
4a-----	.61	.60	.54	.63	.56	.62	.45
4b-----	.58	.60	.55	.65	.68	.75	.42

[1] a = 10-minute collection period after 15-minute running time.
b = 10-minute collection period after 45-minute running time.

Source: Mc Cormick (408, pp. 66-69, tables XXVI-XXIX).

lost, in part, by less free bolting and consequent lowered sifting capacity.

Moisture in wheat and tempering time

Pelshenke and Schäfer (487) studied milling characteristics of Manitoba 5 wheat with a Buhler laboratory mill. The effects of different moisture levels and holding times are shown in table 5. Increased levels of moisture resulted in decreased power consumption, flour yield, and amylose number, and in an increased yield of bran and of starch in bran. A standing time of more than 24 hours at a moisture level of about 16 percent produced essentially no further change than that brought about by 24 hours.

Mambish and Demidov (413) investigated the milling response of different types of wheat to tempering. Tables 6 and 7 show the effects of different holding times and moisture levels on power requirement, production and ash of middlings and flour, and color of flour. Little benefit was derived from moistening above 16 percent or holding for more than 24 hours. Some difference in varietal response was apparent. Recommendations were made for tempering wheats classed according to the percentage of vitreous kernels:

	Vitreous kernels		
	Group 1, over 70 percent	Group 2, 40-70 percent	Group 3, under 40 percent
Characteristics studied			
Moisture to first break ------percent--	16-17.0	15-15.5	14-14.5
Steps in moistening ------number--	2-3	2	2
First standing time ---------hours--	30-36	18-24	10-12
Second standing time before first break----hours--	0.5-1.0	0.3-0.5	0.2-0.3

Anderson (35) studied the effects at 75° F. of tempering time and moisture content on the break release from the Turkey variety wheat. Table 8 gives his results. Anderson concluded that, ignoring the erratic results at 20-percent moisture content, the maximum break release was found at 18-percent moisture after 63 hours.

Anderson (35) measured tempering effects on gluten characteristics of the 1936 crop of Turkey variety wheat by testing straight run flours with the Kansas State College Recording Doughmixer. His experiments were limited to the following holding periods and moistures:

November 1936	- held for 24 hours at 16-, 18-, 20-, and 22-percent moisture content.
April 1937	- held for 24 hours at 16-percent; 63 hours at 17-percent; and 7, 40, and 88 hours at 18-percent moisture content.

In November the best curve was obtained with tempering to 18 percent moisture.

TABLE 5.--*Effects of moisture levels and holding times on milling characteristics of Manitoba 5 wheat*

Conditions and characteristics studied	Experiment 1			Experiment 2	
Water content------percent---	15.2	16.4	17.9	16.0	16.0
Standing time--------hours---	22-24	24	22-24	48	72
Power requirement-------kw---	.24	.20	.19	.18	.19
Flour yield--------percent---	58.2	52.3	51.9	51.0	52.0
Break bran------------do-----	18.6	21.0	24.3	21.7	21.9
Shorts----------------do-----	23.2	26.7	23.8	27.3	24.6
Flour ash-------------do-----	.56	.60	.61	.60	.57
Amylose No.------------------	154	128	114	---	---
Bran ash-----------percent---	4.81	4.82	4.37	---	---
Starch in bran--------do-----	26.5	27.4	31.9	26.5	26.2

Source: Pelshenke and Schafer (487, p. 775, tables 1, 2).

TABLE 6.--*Effect of holding time and moisture level on the milling of two types of wheat*

Wheat[1]	Conditions of experiment			Results of experiment				
				Middlings through 24, retained on IX		Flour through IX		
	Moisture	Duration	Energy for grinding 100 g.	Yield	Ash	Yield	Ash	Color
	Hours	*Percent*	*W./hr.*	*Percent*	*Percent*	*Percent*	*Percent*	
Spring wheat---	---	13.2	3,952	49.1	1.66	11.7	0.91	98
	6	14.9	4,240	48.3	1.20	13.4	.81	81
	10		4,160	48.0	1.18	13.9	.76	79
	12		4,100	48.2	1.16	13.8	.75	79
	18		4,080	48.1	1.19	13.7	.75	79
	24		4,140	48.2	1.30	13.7	.65	80
	48		4,386	48.0	1.35	14.0	.76	83
Winter wheat---	---	12.7	3,712	53.8	1.55	8.1	1.02	122
	6	15.8	4,346	49.2	1.23	10.8	.76	107
	18		4,172	49.0	1.16	10.6	.75	96
	24		4,138	49.3	1.16	10.5	.75	96
	48		4,250	50.1	1.38	11.5	.77	103

Notes: Moisture equilibration in the individual kernels of the wheat Lutescens occurred in 5 hours; in kernels of the wheat Ukrainka in 7 hours.

The amount of wetting of the initial sample of the wheat Lutescens 62 up to 15 percent, and of the wheat Ukrainka up to 16 percent was established by a series of preliminary experiments in which different amounts of moisture were used.

[1] Spring wheat: I Lutescens 62 from Altai region; 38 percent of kernels were vitreous. Winter wheat: IV Ukrainka from Saporoshje region; 53 percent of kernels were vitreous.

Source: Mambish and Demidov (413, p. 21, table 14).

TABLE 7.--*Effect of moisture level on the milling of two types of wheat*

Wheat[1]	Conditions of experiment			Results of experiment				
				Middlings through 24, retained on IX		Flour through IX		
	Moisture	Duration	Energy for grinding 100 g.	Yield	Ash	Yield	Ash	Color
	Percent	*Hours*	*W./hr.*	*Percent*	*Percent*	*Percent*	*Percent*	
Spring wheat---	13.2	12	3,952	50.1	1.66	11.7	0.91	98
	14.0		3,940	49.3	1.39	12.7	.76	86
	19.9		4,100	48.2	1.16	13.8	.75	79
	16.1		4,200	47.6	1.20	14.4	.75	73
Winter wheat---	12.7	24	3,712	53.8	1.55	8.1	1.02	122
	14.6		4,046	51.0	1.40	10.0	.86	115
	15.0		4,098	50.5	1.24	10.2	.75	106
	15.5		4,138	49.4	1.16	10.8	.76	93
	16.0		4,192	48.2	1.15	11.2	.75	93
	17.0		4,190	48.3	1.16	11.3	.76	93

Note: The holding time of the spring wheat Lutescens (group 3 in hardness) amounted to 12 hours; of wheat Ukrainka (group 2 in hardness) amounted to 24 hours. These periods were established by a series of preliminary experiments.

[1] See footnote 1, table 6.

Source: Mambish and Demidov (413, p. 23, table 15).

TABLE 8.--*Break release at 75^{0} F. from Turkey variety wheat as affected by tempering time and moisture content*

Tempering time hour(s)	Break release at moisture content of--				
	14 percent	16 percent	18 percent	20 percent	22 percent
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1--------	17.67	18.80	17.70	13.05	12.05
3--------	19.42	21.20	21.70	23.15	---
24-------	20.58	22.50	22.82	27.90	23.20
40-------	21.50	24.10	25.57	25.38	22.00
63-------	22.85	25.50	26.52	---	24.50
88-------	21.85	24.78	25.25	22.20	21.77
125------	21.80	24.10	24.52	24.67	20.70

Source: Anderson (35, p. 795, table III).

The greater amplitude of curves obtained in April showed the beneficial effect of aging the wheat. In April, wheat tempered to 17 percent for 63 hours and to 18 percent for 7 hours gave the best curves. Anderson concluded that much tempering time could be saved by tempering to 18-percent rather than to 17-percent moisture content.

Swanson (617, 620) studied the effects on milling characteristics of wetting wheat repeatedly (up to six times) and to levels varying from 12- to 28-percent moisture content. All samples were 1,800-gram aliquots of a single uniform lot of Turkey variety wheat that had been harvested and threshed without exposure to rain and had a 10.3-percent moisture content. All samples were moistened to the desired level and were air-dried back to 10 ± 0.25 percent moisture between wettings and after the final wetting. Samples (1,400 grams each) were tempered for milling to 16-percent moisture by adding all but 14 ml. of water the evening before and the last 14 ml. 15 minutes before milling. The milling laboratory was air-conditioned to 80° F. and 70-percent relative humidity. Data recorded from the millings included amounts of break flour, total flour, and ash in the flour (tables 9, 10, 11). Break releases from the treatments showed a small but not entirely consistent trend toward greater releases with higher moisture levels and increased number of wettings. Total flour yield and ash in flour showed no relation to the number of times or degree of wetting of the samples.

Baking tests were made on only a few of the samples. Samples moistened to 28 percent gave the highest loaf volumes and baking scores.

Swanson evaluated kernel hardness and texture of the control and treated wheat by losses during a pearling test and by inspection of kernels cut with a barley cutter (tables 12, 13). The pearling test for hardness showed an increase in pearling loss with added moisture up to 20 to 24 percent, followed by a decrease. A some-

TABLE 9.--*Break flour from wetted wheats*

Moisture to which wetted, percent	Times wetted					
	1	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Check--	12.9	12.6	13.0	12.8	12.6	13.3
12-----	12.4	12.2	13.2	12.7	12.3	13.2
14-----	13.2	12.1	12.0	12.8	12.1	13.0
16-----	12.2	12.5	12.0	12.8	12.5	13.1
18-----	12.6	12.3	12.4	13.1	12.9	13.8
20-----	13.8	13.9	13.0	14.5	13.4	15.3
22-----	13.3	13.9	13.9	14.9	14.9	15.9
24-----	13.8	14.1	14.1	15.0	14.8	15.4
26-----	13.9	13.6	14.2	14.6	14.2	14.7
28-----	14.1	14.4	14.7	14.1	14.4	13.8

Source: Swanson (620, p. 716, table V).

TABLE 10. -- *Total flour from wetted wheats*

Moisture to which wetted, percent	Times wetted					
	1	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Check--	73.9	73.0	74.6	74.7	75.3	74.6
12-----	73.2	73.2	76.3	75.0	73.8	74.6
14-----	74.0	74.5	73.0	74.8	74.0	74.6
16-----	73.0	72.2	73.0	74.3	74.0	72.6
18-----	72.0	72.6	72.2	73.0	73.6	74.3
20-----	76.1	75.7	73.0	75.2	72.5	74.3
22-----	75.0	73.7	73.1	74.8	76.1	76.0
24-----	73.5	73.0	74.9	75.4	75.0	76.2
26-----	75.0	73.6	74.0	75.4	75.3	75.2
28-----	73.6	73.8	75.0	75.2	76.3	75.4

Source: Swanson (620, p. 717, table VI).

TABLE 11.--*Ash of flours from wetted wheats (15-percent moisture basis)*

Moisture to which wetted, percent	Times wetted 1	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Check--	0.43	---	---	---	---	---
12-----	.43	0.39	0.46	0.41	0.41	0.43
14-----	.42	.41	.44	.41	.41	.43
16-----	.40	.43	.44	.42	.40	.43
18-----	.42	.43	.40	.42	.41	.44
20-----	.42	.41	.43	.40	.41	.42
22-----	.41	.40	.42	.43	.44	.42
24-----	.43	.41	.42	.43	.41	.43
26-----	.40	.43	.41	.44	.43	.43
28-----	.43	.45	.41	.43	.44	.41

Source: Swanson (620, p. 718, table VII).

TABLE 12.--*Losses in pearling indicating relative hardness*

Moisture to which wetted, percent	Times wetted 1	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
12-----	32.8	36.6	34.2	34.6	34.8	35.9
14-----	34.5	36.9	37.1	36.4	38.5	40.0
16-----	36.5	38.9	38.2	38.6	40.6	42.3
18-----	37.4	39.0	40.5	43.8	45.7	45.1
20-----	38.4	40.8	44.0	44.8	45.4	46.5
22-----	39.3	40.2	44.6	44.3	45.4	46.1
24-----	39.6	41.6	44.4	44.4	44.3	42.7
26-----	38.5	39.6	43.8	41.4	40.7	41.2
28-----	37.9	39.5	40.9	38.9	39.1	38.0

Source: Swanson (620, p. 718, table VIII).

TABLE 13.--*Mealy or vitreous kernels in samples of fifty kernels*[1]

Moisture to which wetted, percent	Times wetted 1	2	3	4	5	6
Mealy kernels:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Check---------	0	---	---	---	---	---
12------------	4	6	4	2	4	4
14------------	2	2	8	4	4	0
16------------	4	14	4	6	4	6
18------------	8	10	10	10	12	14
20------------	12	12	18	30	24	40
22------------	18	24	26	36	40	34
24------------	24	26	36	44	52	42
26------------	24	36	48	44	60	58
28------------	34	46	54	66	66	50
Vitreous kernels:						
Check---------	98	---	---	---	---	---
12------------	88	92	92	94	92	90
14------------	90	92	88	90	90	90
16------------	88	56	92	90	88	80
18------------	82	46	74	62	54	58
20------------	38	34	36	18	34	14
22------------	30	20	26	16	16	18
24------------	22	10	19	12	10	14
26------------	8	42	14	10	10	8
28------------	10	8	8	2	6	12

[1] Kernels not definitely mealy or vitreous were classified as semivitreous but the percentages have not been included in this table.

Source: Swanson (620, p. 721, table X).

what less regular pearling loss was shown with an increased number of wettings.

A diagram by Köster (367) which was reproduced by Galter (230) showed the relation between different moistures of four wheats and their degree of hardness in Brabender units. While only three points were plotted for each wheat, the relationship between the decrease in resistance to crushing and the increase in moisture was essentially linear. The absolute hardness values at a given moisture content were distinctive for each wheat studied. Numerical values (hardness in Brabender units) taken from the graph were as follows:

Moisture in wheat, percent:	Hardness values of-- Hard Argentine	Manitoba	Small Argentine	Tassilo
13	590	490	390	300
14	530	435	350	275
15	475	395	315	250
16	[1] 420	355	[1] 280	220
17	[1] 362	320	[1] 248	---
18	[1] 305	[1] 280	[1] 208	---

---

[1] From extrapolated data.

At a hardness of 220 (considered "normal" for taking to 1 break) these wheats showed the following moisture content: Hard Argentine and Manitoba, 19.5 percent; Small Argentine, 17.75 percent; and Tassilo, 16 percent. The results for the first three wheats were from extrapolated data.

Seeborg and Barmore (587) studied the influence of various tempering moistures on soft wheat from the Pacific Northwest. Five 100-gram samples of each of three

TABLE 14.--*Effect of moisture on flour yield, flour ash, and milling behavior of three Pacific Northwest wheats*

Variety	Milling moisture of--				
	9 percent	11 percent	13 percent	15 percent	17 percent
	Flour yield, percent				
Elmar----	76	76	75	73	71
Brevor---	72	70	66	66	61
Rex------	71	67	63	58	53
	Ash in flour, percent				
Elmar----	0.40	0.38	0.36	0.36	0.36
Brevor---	.37	.35	.32	.32	.32
Rex------	.40	.34	.30	.28	.28
	Break release, percent				
Elmar----	56	55	54	53	52
Brevor---	51	50	49	43	43
Rex------	50	50	49	49	47
	Bran yield, percent				
Elmar----	16	17	18	20	22
Brevor---	19	21	24	26	28
Rex------	18	21	25	28	32

Source: Seeborg and Barmore (587, figs. 2-5).

varieties were tempered and then milled on a Buhler mill modified for micromilling. With an increasing moisture level a decrease was found in flour yield, ash in flour, and break release (table 14). Bran yield increased. It is apparent that the varieties responded in different degrees to changes in moisture level.

The effect of length of tempering periods and amount of tempering water on granulation of flour--and incidentally on some other properties of flour--were studied by Wichser and Shellenberger (650). In one experiment 2,000-gram samples of hard red winter and of hard red spring wheat were tempered to 16-percent moisture content and held for 48, 24, 18, and 4 hours. The samples were milled in sequence, with the same percentage break releases and reduction roll settings, on Allis stands. Graphically presented data on the size of the flour particles showed no differences in granulation of the flour. Wichser and Shellenberger reported no differences in ash and protein contents, farinograms or mixograms, or baked products.

An experiment in which three samples of hard red winter wheat were tempered to 16, 12, and 20 percent moisture content, respectively, showed some differences in the granulation of the flours milled from them. However, flour extractions varied, being 72, 66, and 64 percent for stock moistures of 16, 12, and 20 percent, respectively, and the differences in granulation were thought to be a function of the loss in flour extraction.

Dedrick (148) studied the effect of varying the moisture content of tempered wheat on the removal of dirt, fiber, beard, and outer pericarp, and on the quality and the quantity of milled products. He used a medium soft American wheat of 10 percent natural moisture. After aspiration, light scouring, and washing, the wheat was dampened to 15.4 percent and four samples of equal weight were stored in different types of lightly covered containers for 14 days at 18° C. Variation in loss of moisture during storage resulted in tempered wheats of different moisture content. Following three successive scourings and a prebreak on a smooth roll, the wheats were milled. Results are presented in table 15. The importance of maintaining moisture of tempered wheat during storage is apparent from the excessive scouring loss and the poor quality and quantity of flour obtained from the sample of 11.71-percent moisture content that had been stored in a wooden box. The bread from this sample was darker, smaller in volume, and poorer in pore formation than bread from the other flours.

Vermeylen (637) conducted a series of laboratory experiments on conditioning and evaluated the results with the Farinograph. All experiments in which tempering could be compared with dry milling showed that tempering brought about some improvement in gluten characteristics. The experiments primarily concerned with cold conditioning are given in table 16. With some wheats tempering gave adequate improvement (Experiments 3, 6, 9, 13), but with the particular wheat used for experiment 12, tempering gave insufficient improvement and Vermeylen recommended the use of heat. The results of experiments

TABLE 15.--*Effects of different methods of storage of tempered wheat on moisture, loss in scouring, and quality and quantity of some milled products*

Storage container	Grain moisture	Scouring loss	To bran roll over sieve 24	Break flour through 10XX	Straight run flour--	
					Moisture	Color score
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	
Glass------------	14.52	0.70	24.16	25.12	13.07	100
Clay-------------	14.31	.77	23.10	23.80	12.98	99.8
Metal------------	14.27	.80	22.15	22.85	12.75	99.5
Wood-------------	11.71	1.27	19.38	17.48	10.80	95.0

Source: Dedrick (148, p. 419).

3, 6, and 13 showed that better farinograms were obtained by adding water in several steps rather than all at one time. Since the holding period following each moistening was 24 hours, the overall standing times for moistening in two and three steps were 48 and 72 hours, respectively. Vermeylen concluded that, in general, 48 hours appeared to be the optimum holding period. For some wheats a standing time of 72 hours was too long (experiments 9 and 13).

Some mill practices

Surveys of tempering practices in commercial mills of the United States have shown that there was a great range in the tempering times used for hard winter wheat. An Association of Operative Millers (A.O.M.) survey of 38 mills in 1925 (Stark, 608) indicated a variation from 15 to 72 hours. A survey by McCormick (408) of 76 mills in 1929 found a variation from 4-2/3 to 72 hours. Both surveys reported 20 to 30 hours as the most frequently used period. These surveys did not give the physical character or natural moisture of the wheats. Robinson (527) pointed out that tempering time alone is meaningless without consideration of these factors. Atkinson (43) stated in 1957 that current practice in the United States favors 24 hours as a minimum tempering period for hard wheats.

From his experience and observation in the milling industry in Switzerland, Weber (648) pointed out that by individual treatment of wheat varieties a miller could obtain high yields of low ash flours without the expense of installing and operating a conditioner. He made this clear by a specific illustration showing the wrong and right way of preparing a certain wheat mixture for milling. He used three methods of preparation. His statements concerning milling results (some of which were also presented in a graph in which grams of wet gluten were plotted against mill streams) for each method follow:

> *Method 1.*--A mixture of four wheats was washed. Moisture of the entire mixture was 16.5 percent. Moistures of the component wheats were Manitoba, 14.0; hard winter, 17.2; red winter, 17.5; domestic, 18.5 percent. The domestic and red winter wheats were reduced quickly because of their soft character, while the Manitoba was released later. Results from milling were poor and separation of bran from endosperm was difficult. Sizings and early reductions produced gluten-weak flour and the tailings streams were too good.
>
> *Method 2.*--By treating each wheat separately, a mixture was prepared in which each component had a moisture content of 16.5 percent. Breaks and reductions were noticeably improved when this mixture was milled, but the bran broke excessively and the middle flour streams were still too good.
>
> *Method 3.*--Each wheat was brought to its approximate optimum moisture before the mixture was made and milled. In accordance with the moistures recommended by Weber for different types of wheat, the grain was tempered to the following moisture content: Manitoba, 18-19.5; hard winter, 16.5-17.5; red winter, 16-17; and domestic, 15-15.5 percent. The middlings and dunst of the hard

TABLE 16.--*Effects of moisture addition and holding time on gluten characteristics of four lots of Manitoba wheat*

Wheat and experiment no.	Moisture added			Holding time after each step	Results shown by farinograms
	First step	Second step	Third step		
Manitoba 2:					
Lot a-	*Percent*	*Percent*	*Percent*	*Hours*	
1a[1]	0	0	0	0	Slow development, immediate weakening.
3a	6	0	0	24	Elasticity increased.
3b	3	3	0	24	Stability increased.
3c	2	2	2	24	Elasticity and stability improved.
6a	5	0	0	24	Elasticity improved, consistency continually increased.
6b	2.5	2.5	0	24	Elasticity increased, curve straighter.
Lot b-					
9b	[2](5)	0	0	48	Large and sufficient improvement.
9c	(5)	0	0	72	Treatment too long.
Manitoba 4:					
Lot d-					
13b	(5)	0	0	24	Elasticity and stability improved, dough formation not improved.
13c	(2.5)	(2.5)	0	24	General improvement.
13d	(5)	0	0	72	Treatment too long, elasticity decreased.
Lot c-					
12b	(5)	0	0	24	Elasticity and stability increased.
12c	(5)	0	0	48	Stability better than 12b.
12d	(5)	0	0	72	Stability better than 12c.

[1] Control, milled dry.

[2] The figures in parentheses are inferred from the text.

Source: Vermeylen (637, pp. 509-517).

foreign wheat were reduced with relatively light roll pressure along with the soft wheat stocks instead of being shifted to the tailings. The bran broke into large pieces and was easily separated from the endosperm. More flour of better quality was produced at the head of the mill than when the wheat mixture was prepared by either Method 1 or Method 2.

Tempering split wheat

Hodler (307) studied the effects of splitting the wheat prior to tempering on the rapidity of mellowing of the endosperm and on the quality of the flour. A thoroughly mixed lot of hard red winter wheats was divided into 32 samples. Half the samples were passed between smooth rolls at a

TABLE 17.--*Chemical analysis of flours on 15-percent moisture basis*

Wheat moisture, percent	Tempering time	Flour from unsplit grain			Flour from split grain		
		Moisture	Ash	Absorption	Moisture	Ash	Absorption
	Hours	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
16---------	0.75	12.9	0.444	57.1	12.2	0.415	56.9
	1.5	12.5	.429	57.5	12.8	.423	56.6
	2.0	12.3	.428	58.2	12.6	.405	56.2
	4.0	13.6	.429	57.7	13.5	.409	55.7
	8.0	12.7	.428	57.2	12.9	.414	57.8
	18.0	12.9	.444	56.7	12.7	.425	56.8
	30.0	12.7	.421	58.0	12.8	.406	56.6
	48.0	13.2	.423	56.7	13.1	.427	55.3
18--------	0.75	13.6	.455	55.1	14.5	.413	55.5
	1.5	14.1	.416	57.2	14.8	.427	57.7
	2.0	13.6	.453	56.2	13.6	.413	54.7
	4.0	13.7	.430	56.0	13.3	.416	55.7
	8.0	13.7	.441	55.6	13.6	.429	55.9
	18.0	13.6	.433	56.5	13.8	.430	54.8
	30.0	13.6	.449	54.5	13.9	.422	56.1
	48.0	13.8	.442	54.3	13.9	.430	54.1

Source: Hodler (307, p. 26, table 1).

1.5:1 differential to split the kernels. Half the split and half of the unsplit samples were then tempered to 16-percent and half of each to 18-percent moisture content for times ranging from 0.75 to 48 hours. The samples were milled on an Allis experimental mill with as uniform extraction as possible. Chemical analyses of the flours are given in table 17. Ash content of flour from the split wheat was lower than that of flour from the whole grain in all but two cases. Swanson-Working Recording Doughmixer tests and Pekar color tests were also made. From the Doughmixer curves Hodler concluded that splitting the wheat before tempering speeded up the tempering effect during the first few hours. A 0.75-hour temper for the split wheat gave as favorable results as a 4-hour temper for the whole grain. Pekar color tests showed no significant color variations.

Biochemical effects

Biochemical changes brought about by conditioning have been investigated by several workers. Losev (400) determined those that occurred in a commercial mixture containing 83 percent of soft and 17 percent of hard wheat during three methods of conditioning. The grain was thoroughly cleaned and four 200-gram samples were handpicked to remove all damaged kernels. Three samples to be conditioned were immersed in water for 30 to 35 seconds and excess water was removed by sieving and blotting. Additional water was added in the following ways:

1. Cold conditioning.--Grain was damped to 16.5 percent moisture with water at 18° C. and held at that temperature for 24 hours.
2. Warm conditioning.--Grain was damped to 16.5 percent with water at 35° C. and held at 27° C. for 24 hours.
3. Hot conditioning.--Grain was damped to 19 percent with water at 18° C., then spread on a sieve and placed in an oven that had been preheated to 85° C. and saturated with steam. After 30 minutes the grain was spread out in a layer 1 cm. deep and cooled to room temperature.

The three conditioned samples and the control (11.4-percent moisture) were milled to 85-percent extraction by 10 passes through an "Excelsior" laboratory mill. Moisture and ash determinations were made immediately; all other tests, after the flour had been stored for 7 days. The effects of conditioning are shown in table 18.

Biochemical changes found as a result of conditioning included changes in diastatic activity, catalase activity, and amount of reducing sugars. No changes were found in the total acidity, pH, or amount of amino nitrogen. The yield of flour and the amount of ash were improved. Losev attributed the lower ash of the conditioned samples to the removal of dust by immersion in water prior to conditioning. The changes in coagulable protein and other properties of dough as a result of the conditioning methods were reflected in the quality of bread made from the flour. Bread baked from flour from the cold-conditioned wheat had the best properties. Losev pointed out, however, that he did not attempt to establish optimum conditioning methods, but only to establish what biochemical changes took place during conditioning so that further studies might be undertaken to control them.

Sosedov and others (602) studied the biochemical changes occurring in three wheats subjected to cold conditioning. Grain was tempered to 16 percent moisture and held for 45 to 48 hours at 18° C. Results are given in table 19. For the most part, the results showed little consistency. In their summary, they pointed out that as a result of cold conditioning there was an increase in the reducing sugars and in the activity of diastase and catalase. However, when the diastatic activity was determined by the Rumsey method rather than by Sosedov's method, diastatic activity of flours from cold-conditioned wheat was less than that of flours from unconditioned wheats.

Data of Loeb (397) are reported in an article by Kosmin (369). Loeb dampened samples of different wheats to 16-percent moisture content and let them stand at room temperature for 24 hours before milling. The diastatic activity of the flours from control and tempered wheats was determined. Activity was expressed as percentage of maltose which resulted from incubation of a flour suspension for 2 hours at 27° C.:

		Maltose in flour from--	
	Moisture	Unconditioned wheat	Conditioned wheat
Wheat:	*Percent*	*Percent*	*Percent*
Hard winter Pacific ..	9.37	2.71	1.79
South Russian	12.57	2.73	2.00
Manitoba	13.25	3.06	2.58

According to Kosmin, Loeb attributed the lower diastatic activity of flour from the conditioned wheat to a lower germ content as indicated by less bran in the flour.

Anderson (35) reported a decrease in diastatic activity in Turkey variety wheat with an increase in moisture content at a fixed tempering time of 24 hours--at a moisture content of 16, 18, 20, and 22 percent, the respective diastatic activity was 151, 124, 89, and 84.

Data of McCormick (408, p. 76, table XXXV) showed that diastatic activity of a hard red winter wheat decreased with an increase in tempering period. Moisture was held constant at 15 percent. Figures for diastatic activity were given as the differences between determinations of sugars at 25° and at 63° C.:

	Diastatic activity	
Tempering period, hours	Flour	Wheat
3	52.1	33.5
24	32.9	18.6
48	38.9	16.6
72	26.8	12.1

Swanson (615), apparently discussing these data, explained this decrease in diastatic activity by assuming that the increase in the diastatic activity at the moisture contents used in tempering wheat is accompanied by a greater increase in the rate of sugar consumption by respiration.

Tague (628) determined the flour yield and certain chemical properties of the flour from Kanred, Turkey (or Kharkof), and Arizona White wheat tempered at 5°, 20°, and 40° C. for periods of 24, 48, and 72 hours. The wheats were milled by several passes through a laboratory burr mill. Two moisture levels were originally selected, 15.5 and 18.0 percent, but all samples tempered to 18 percent proved sticky, with flour yields below those for untempered grain. Results were similar for all three varieties; only results for the Kanred variety are presented in table 20. Slight chemical changes were apparent at 20° but were a little more pronounced at 40°. For the most part tempering resulted in easier milling but, with a temperature of 40° and a holding period of 72 hours, the flour milled sticky. Increased flour yield was noted at 20° with little further change at 40°. Tague concluded that the improved milling quality of tempered wheat is due chiefly to physical changes.

TABLE 18.--*Analyses of flour and dough and characteristics of bread from unconditioned wheat and wheat conditioned by three methods*

Characteristics studied	Control	Cold, 18° C.	Warm, 27° C.	Hot, 30' at 85° C.
Flour:				
Yield---------percent--	85.0	87.1	87.3	87.5
Moisture---------do----	11.4	14.4	14.1	14.1
Ash-------------do----	1.55	1.30	1.28	1.30
Color------------------	Dirty gray	Whitest	Darker	Reddish.
Maltose--mg./10 grams flour----------------	167.9	147.3	117.3	120.6
Reducing sugars--percent of control---	100	121.9	146.9	137.5
Catalase activity during fermentation time of[1]--				
0-----------minutes--	12.75	11.47	16.09	.80
180------------do----	17.00	13.20	33.00	13.56
240------------do----	22.00	15.50	34.15	17.36
280------------do----	26.56	14.91	29.00	12.00
280 minutes + 10 minutes at 60° C.----------	.00	1.73	.26	.00
Acidity:				
Total, Leman's degrees-	2.4	2.5	2.5	2.4
pH--------------------	6.6	6.4	6.7	6.6
mg. amino N/g. dry flour----------------	.35	.37	.38	.37
Coagulable proteins in fermentation time of[2]--				
0-----------minutes--	6.8	5.4	21.8	5.3
180------------do----	25.1	36.9	21.2	35.1
240------------do----	47.5	50.0	18.3	---
280------------do----	40.3	43.0	20.7	36.9
280 + 10 minutes at 60° C.-------------	38.6	36.0	19.8	26.2
0 + 10 minutes at 60° C.----------	1.7	7.0	.9	10.7
Dough volumes at stages of fermentation:[3]				
Before first punch---	100	117.2	96.6	106.9
Before second punch--	100	116.6	102.8	111.1
At end of fermentation--------------	100	115.8	92.1	110.5
Bread characteristics:				
Color-----------------	Dirty gray	Lightest	Dark	Reddish.
Texture---------------	Uneven	Fine, thin-walled	Even	Thick, tough walls.
Shape-----------------	Spread out, inelastic	Good, elastic	Spread out, inelastic	Rounded.

[1] Ml.N/10 $KMnO_4$/gram flour. [2] Percentage of water-soluble protein. [3] Percentage of control.

Source: Losev (400, pp. 11-13, table 1-5)

TABLE 19.--*Biochemical analyses and baking characteristics of unconditioned and cold-conditioned wheat*

Characteristics studied	Wheat and treatment					
	Kreimka No. 29		Livestens No. 59		Kreimka No. 36	
	Control	Cold-cond. 48 hr.	Control	Cold-cond. 46 hr.	Control	Cold-cond. 45 hr.
Vitreous kernels----percent--	31.6	31.6	45.6	45.6	55.6	55.6
Moisture---------------do----	12.0	16.5	11.1	15.2	11.5	15.9
Gluten:						
Wet------------------do----	18.40	19.04	34.62	33.62	29.20	28.60
Dry------------------do----	6.24	6.08	11.4	11.2	9.60	9.76
Swelling No.---------------	12.80	15.10	23.00	22.10	14.7	11.0
pH---------------------------	6.31	6.48	6.79	6.46	6.88	6.53
Soluble carbohydrates:						
Reducing (Bertram)-percent--	.18	.23	.06	.31	.18	.22
Reducing (Issekut)----mg.--	43.64	44.73	31.14	52.18	44.52	49.10
Fructose----------percent--	3.01	2.75	2.29	2.17	2.45	2.26
Maltose--------------do----	1.27	.79	.86	1.12	1.23	1.01
Diastatic activity:						
Rumsey method--------------	282.8	135.3	222.1	202.3	218.9	147.2
Sosedov method-------------	503.9	546	705.8	724.2	541.3	542.3
Catalase activity, ml. N/10 $KMnO_4$----------------------	27.7	29.6	39.0	---	26.7	28.4
Alveograph data:						
Stiffness, "P"-------------	118	75.5	53.0	52.0	72.7	124.0
Extensibility, "G"---------	14.7	21.6	24.9	26.1	22.0	15.7
Work, "W," ergs------------	172	209	173	173	219	212
Baking characteristics:						
H:d------------------------	0.30	0.36	0.41	0.39	0.38	0.33
Volume---------------------	372	390	387	393	366	303
Texture--------------------	Uneven, thick wall.	Uneven, thick wall.	Fine uneven.	Thin-walled, even.	Uneven.	Even.
Crumb quality--------------	Elastic, resilient.	Tightened.	Quite good.	Not springy.	Elastic, resilient.	Elastic resilient.

Source: Sosedov et al. (602, pp. 876-877).

Use of Additives in Tempering Water

Several workers have added substances to the tempering water for the purpose of either shortening the tempering time, facilitating the separation of bran and endosperm, or affecting the quality of the flour milled from the wheat. Sullivan (612) obtained a drastic reduction in the time needed to temper wheat samples for milling for laboratory tests by the use of 0.1 percent Aerosol OT (sodium dioctyl sulfosuccinate) in place of tap water for tempering. The tempering time required for hard spring and winter wheats was cut from a period of 8 to 18 hours or overnight, using tap water, to one of 2 to 3 hours, using aerosol. No differences were observed in

TABLE 20.--*Yield and chemical properties of flour from Kanred variety wheat tempered to 15.5-percent moisture content*

Hours tempered	Temperature	Hydrogen-ion concentration	Total acidity[1]	Water-soluble phosphorus	Titrable nitrogen[1]	Yield of flour[2]	Remarks
	°C.	*pH*	*Percent*	*Percent (d.b.)*	*Cc.*	*Grams*	
----------	---	6.20	1.7	0.0361	4.2	68	Brittle and hard.
24--------	5	6.20	1.7	.0359	4.2	67	Ground fairly well.
48--------	5	6.22	1.8	.0360	4.1	69	
72--------	5	6.20	1.7	.0361	4.3	68	
24--------	20	6.17	1.7	.0361	4.4	70	
48--------	20	6.19	1.7	.0362	4.6	72	Ground well.
72--------	20	6.13	1.8	.0380	4.5	71	
24--------	40	6.06	2.0	.0376	4.6	72	
48--------	40	6.00	2.0	.0379	4.6	72	
72--------	40	6.00	2.0	.0378	4.8	70	Sticky.

[1] Expressed as number of cc. N/10 sodium hydroxide required to titrate 10 g. flour.
[2] Expressed as number of grams of flour obtained from 100 grams of wheat.

Source: Tague (628, p. 274, table I).

milling yield, ash, protein, mixing curve, or baking results of the flours obtained after the two different tempering methods.

The Victor Chemical Works carried on some experiments using the wetting agents Victawet 35B and Victawet 58B in tempering water.[4] Although penetration of water into the kernel was speeded up, the wheat was harder to mill than the control sample and the milled flour had a strong odor and taste.

Altrogge (25) reported briefly on the addition of 2 percent of a 5-percent $NaHCO_3$ aqueous solution to a German domestic wheat already dampened to 16.5-percent moisture content in a silo. After a 1-hour tempering period the wheat was discolored, varying in color from dark yellow to light green. Compared with washed grain, this wheat showed better loosening of the coat in the polishing and brush machines but poorer milling and smaller semolina yield.

Kranz (306, German patent 812,144) invented a process which he claimed increased the yield of flour from wheat. The process consisted of drying the grain to 14-percent moisture content, spraying it with the amount of a 2-percent aqueous solution of methylcellulose necessary to increase the moisture of the grain to 16 percent, and allowing the wheat to stand for 0.5 to 1 hour before milling. As a result of this treatment the bran was considerably moister and tougher than the endosperm, and a more complete separation of the bran from the endosperm was attained. Alternative cementing materials suggested were ethylcellulose, tragacanth, gum arabic, karaya gum, alginate, agar, starch paste, dextrins, casein glue, isinglass, and polyphosphates with viscous properties. The patent also suggested that the grain, dampened with the cementing solution, could be treated with formaldehyde to strengthen the film formed, thus enhancing the toughening effect on the bran.

Robinson (528) found that at 68° F. absorption of water by wheat increased with an increase in alkalinity of the tempering water up to 400 p.p.m. of NaOH:

NaOH, p.p.m.	Absorption of water by-- No. 1 northern wheat	Absorption of water by-- No. 3 northern wheat
	Percent	*Percent*
0	27.7	27.2
75	28.5	27.1
400	29.5	27.7
800	29.4	27.6

Baking tests from other studies indicated that addition to the tempering water of alkali up to 50 p.p.m. had no unfavorable effect on the bread.

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[4] Personal communication from R. A. Barackman (1956).

In another experiment Robinson used chlorine in the tempering water. Ten-pound samples of wheat were tempered for 8 hours in the following solutions: Tap water, tap water containing 50 p.p.m. of free chlorine, and tap water containing 250 p.p.m. of free chlorine. Analyses and baking tests were made on straight run flour from an experimental mill. From each sample one portion of flour was tested when 1 week old, one portion when 4 months old, and a third portion after it was matured with Novadel and stored for 4 months. Flours from samples tempered with chlorine-containing water showed a smaller increase in acid number of the fats during aging than did those tempered with water alone.

Walden and others (645) investigated the desirability of adding potassium bromate to the tempering water instead of to the flour. The distribution of potassium bromate in the various milling fractions when it was added at a level of 2.5 mg./100 g. wheat to the tempering water was as follows:

		Bromate	
	Wheat	Content	Recovery
Milling fraction:	*Percent*	*Mg./100 g. fraction*	*Mg./100 g. wheat*
Flour	68.0	0.27	0.18
Low grade, Red Dog	2.0	.57	.01
Shorts	5.5	3.27	.18
Bran	24.5	8.65	2.12
Total			2.49

It was determined by baking tests that loaf volumes obtained from flours whose bromate content originated from additions to the wheat were similar to those obtained from flours to which bromate was added at dough mixing. Comparisons were made on the basis of actual bromate content of the flour. It was concluded that the addition of bromate to the tempering water had no advantage over procedures in which it was added directly to the flour.

Fritsch (220) claimed that gluten properties of wheat could be changed by introducing certain substances such as organic acids into the kernels by the Miag-Wille-Fritsch outer-layer treatment. Cleve (134) (see p. 64) improved the baking quality of flour by conditioning wheat by the outer-layer process with a lactic acid solution. However, no comparison was made with effects produced by using water alone in the treatment.

Markley (417) investigated the effects upon wheat proteins of varying the hydrogen ion concentration of the tempering water. The wheats he used were Hybrid 128, a soft white club wheat of very low protein content; soft Federation wheat from Oregon; a blend of central Missouri soft red wheats; and a hard red winter wheat of low protein content from Kansas. Six 200-gram portions of each sample were placed in pint Mason jars and 20 ml., respectively, of distilled water, 0.1 N H_2SO_4, 0.1 N NaOH, 0.01 N H_2SO_4, 0.01 N NaOH, and 0.05 N Na_2SO_4 were added. The jars were covered without rubbers, the contents thoroughly shaken, and the whole stored at 30° C. Analyses were made after 20 and 92 hours (Hybrid 128 excepted) for moisture, water-soluble nitrogen, titrable acidity, amino acids by Sørensen's formol titration, and nonprotein nitrogen by Ritthausen's copper precipitation method. The tests were also run on dry wheat.

Treatment with 0.1 N H_2SO_4 raised titrable acidity in all varieties. Effects of other treatments on titrable acidity were erratic; no consistent changes were apparent. Analyses for nitrogen showed that there were some varietal differences in results between the soft Federation, soft red, and hard winter wheats. However, because of the rather erratic and inconsistent nature of the results obtained at 20 and 92 hours and the lack of consistent varietal differences, only data for the hard winter wheat are reproduced here (table 21). These, together with Markley's very generalized conclusions, give a picture of the equivocal results. Markley's conclusions were: "When compared with water used for tempering, 0.1 N acid and alkali depress the amino acid content at 20 hrs. At 92 hrs. there are no consistent differences from water. Na_2SO_4 tends to depress the amino acids at all times. The 0.01 N acid and alkali have no significant variations from water.

"The 0.1 N acid and alkali tend to increase the water-soluble nitrogen and the copper non-precipitable nitrogen at 20 hrs., but do not differ materially from water at 92 hrs. Na_2SO_4 is a depressant at all times."

Cold Milling

Early work

In 1928 Loizillon (398) reported on the use of artificially cooled air in the milling process at a mill in Briey, France. The circulating air in the milling system was

TABLE 21. --*Effects of hydrogen ion concentration in tempering water on chemical composition of hard winter wheat*

Tempered with	Time at 30° C.	Moisture	Acidity H_2SO_4	Amino N	Water sol. N	Cu Non-pptd. N
	Hours	*Percent*	*Cc.*	*Percent*	*Percent*	*Percent*
None (control)---	0	10.78	2.45	0.0187	0.307	0.0696
Distilled water--	20	16.06	3.05	.0213	.341	.0852
Distilled water--	92	16.54	2.75	.0164	.333	.0912
0.1 N H_2SO_4------	20	16.58	3.7	.0171	.332	.0886
0.1 N H_2SO_4------	92	16.58	3.7	.0178	.322	.0886
0.1 N NaOH-------	20	16.49	2.65	.0164	.356	.0886
0.1 N NaOH-------	92	16.41	2.25	.0143	.327	.0886
0.01 N H_2SO_4-----	20	17.00	2.55	.0179	.338	.0892
0.01 N H_2SO_4-----	92	16.36	2.65	.0185	.319	.0852
0.01 N NaOH------	20	16.17	3.05	.0156	.331	.0884
0.01 N NaOH------	92	16.21	2.6	.0171	.322	.0884
0.05 N Na_2SO_4----	20	16.82	2.6	.0157	.332	.0832
0.05 N Na_2SO_4----	92	15.96	3.55	.0156	.304	.0910

All results except moisture are calculated to 15-percent moisture basis.

Source: Markley (417, p. 161, table IV).

cooled and dried with a refrigerator element. Loizillon claimed certain benefits from cold milling: Increase of milling yield through elimination of evaporative loss of moisture from stock and better separation of bran from endosperm, prevention of gluten damage by heat of grinding, increase of water-binding power of gluten, and greater yield from the flour in baking. Grain with 20-percent moisture content could be milled at temperatures which would not damage the gluten. This fact meant that grain could receive the benefits of washing (among them the removal of some of the harmful "cerealin"[5]) but did not have to be subjected to moisture loss through drying.

According to Loizillon, grain (sp. heat 0.7) would be raised to 42° C. from an initial temperature of 15° by the usual milling process. Semolina particles would be heated for a fraction of a second to a temperature high enough to damage the gluten. He reported that flour heated at 35° for 20 minutes lost 0.6 percent of its water-binding property and lost the same amount when brought to the same temperature by mechanical treatment. Loizillon attributed the poor quality of the gluten present in later flour streams to damage from heat of grinding. He presented data from cold milling to substantiate this view. A sample taken after the first reduction was alternately sieved and processed further by the cold method with the following results:

	Amount of flour	Dry gluten content	Water content of wet gluten
Siftings:	*Percent*	*Percent*	*Percent*
1..........................	46	7.56	68.75
2..........................	21.8	7.59	69.64
3..........................	14.6	8.10	70.26
4..........................	11.2	8.73	68.94

The water content of wet gluten increased after all but the last processing. Loizillon stated that, in general, wet gluten from flour normally processed had a water content of 65 to 68 percent, seldom 69 percent, whereas the wet gluten from flour of cold-milled wheat had a minimum water content of 70 percent. He also reported that flour from a sample of stock taken before the reduction rolls and milled cold was compared with flour from the stock after it had passed through the reduction rolls; the water content of the wet gluten from the former was 2 percent higher than that from the latter.

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[5] A term formerly used to denote the enzyme-rich fraction of the grain which was deleterious to baking quality of the flour.

Fleurent (196) conceded that Loizillon's cold milling method minimized the effect of heat on gluten, but he strongly questioned the reliability of water-binding power of gluten as a criterion of baking quality of flour. He also pointed out that determination of wet gluten, even by the same person, frequently showed an error of 2 percent. Such an error would be 50 percent of the extreme fluctuation of the difference between 65- and 68-percent water content of wet gluten. Fleurent thought that enzymes making up "cerealin" could not be washed out of the grain because of the semipermeable nature of the kernel membranes.

Hopf (317, 318) considered some of the problems of cold milling. In his opinion, 7 hp./hr. would be needed to mill 100 kg. of grain instead of the 3 hp./hr. stated by Loizillon. For calculating the rise in temperature of the stock in normal milling during the first break, Hopf (317) chose the passage of rye through a roll 600 by 300 mm. with 4.5 flutes/cm., because he claimed that wheat did not warm up much during the breaks. He calculated that the temperature of the rye would be raised from 15° to 33.2° C. in the first break and to 45° to 60° in the entire milling process. The stock would be subject to the high temperatures for only a fraction of a second. Hopf (317) suggested the use of cold in low milling of rye: Chill the stock to 0° after cleaning and before milling. Direct cold air (-5° to -10°) to the surface of the fast roll and force it with the grain through the nip of the rolls where cooling is most needed. Hopf claimed that the temperature between the rolls would be about 30° and that the stock would leave the rolls at 15° to 17° at the highest. No evaporation of moisture would occur because of the low temperature. According to Hopf, cooling the rolls with water was impractical and very expensive.

Hopf (318) compared the loss of moisture from milling stock during cold milling with the loss during normal milling. His calculations were based on milling rye through six breaks. For normal milling he assumed a 2-percent loss of moisture from rather moist rye, outer air 50 percent saturated at a temperature of 18° C., and a temperature of 35° for the air after the rolls. The maximum extraction of water from the stock was calculated to be 31.83 g./m.^{3} or 57g./kg. rye or 5.7 percent. With a 2-percent loss of water the aspirating air would be only 35 percent saturated. In cold milling, assuming outer air as for the normal milling and a temperature of -10° for air to the aspirator, no moisture would be extracted from the stock if the air temperature could be maintained at -10° during and after passages through the rolls. Actually the cold air would be warmed to at least 0° and this would lead to an extraction of 0.4 percent water in contrast with 2-percent extraction during normal milling. If the aspirating air became heated to +10°, calculation gave a figure of 1.3 percent for extraction of water from the rye stock during the six breaks. Pasting could not occur if the walls of the tubes were warmer than the air and the stock, a fact which would also be applicable to pneumatic conveying.

Hopf (317) conducted an experiment to find out whether cold affected the gluten. A 1:1 mixture of flour from German domestic wheat and from spelt was kept at -2° C. for 24 hours. In the first series of tests four samples of the chilled flour were made into doughs using water of different temperatures. In the second series, doughs were made from flours of different temperatures, using, in each test, water of the same temperature as the flour. Results were as follows:

	Water temp.,	Dough temp.,	Wet gluten	Dry gluten	Gluten characteristics
Test Series 1:	°C.	°C.	*Percent*	*Percent*	
1.......	+7	+5.5	32.40	10.80	Slightly elastic, tough, and somewhat hard.
2.......	+25	+14.0	34.50	11.00	Elastic, tough, medium hard.
3.......	+40	+18.0	35.20	10.80	Slightly elastic, somewhat soft.
4.......	+60	+24.0	34.80	10.80	Slightly elastic, short.
Series 2:					
1a......	+1	+1	36.00	11.15	Hardest.
2a......	+25	+25	36.50	11.20	
3a......	+40	+40	37.50	11.60	
4a......	+60	+60	39.00	12.10	Short, elastic.

Hopf concluded that gluten was not affected by temperatures below 25° and that chilled gluten attained elasticity and softness only if the flour was brought to a temperature of about 35° and the water for making the dough had a temperature of about 50°. He also concluded that gluten was not damaged during cold milling.

Hopf (317) listed the following advantages for cold milling as:

No loss of water from the stock.

A gain of at least 1 percent of water added during damping or conditioning because grain can be milled with more moisture.

The possibility of storing flour with 16-percent moisture content at 0° C.

Prevention of damage to the gluten, especially gluten in flours from the tail of the mill.

Improvement of baking quality of special flour.

A higher flour extraction if Loizillon's claim for easier separation of flour from bran is correct.

No damage of grain by moths.

Recent work

Scheuch (568) stated that the baking quality of flour is not harmed by low temperatures but that chilled or frozen flour should be slowly warmed to room temperature before it is used for baking.

Pelshenke (486) measured crushing gap temperatures over a period of 1 year in three different mills. He pointed out that this temperature depended on the distance between the grinding rolls and the temperature of the milling stock, and that a higher temperature was found when the milling was done with corrugations dull to dull, as compared with sharp to sharp. Table 22 gives his summary of data. The crushing gap temperature and the temperature of the millstock increased from the front to the back grind. Climatic changes produced only small variations in the heating in individual passages. Variations from mill to mill were large. The average temperature in the crushing gap was 30° C.; the highest was 51.5°. Pelshenke concluded that crushing gap temperatures could have little effect on baking quality. Temperatures in the back passages rose to above 45° on very hot days, but the amount of flour produced there was relatively small. In the front passages, the temperatures did not go over 35°. Pelshenke also stated that the heating of the mill stock is the most important factor in loss of moisture by evaporation and that cool grinding is the only way to achieve low evaporation.

Schäfer (see 14) reported briefly on an experiment with cold milling. Wheat was cooled to -18° C. and then milled at a temperature between -6° and -10° C. The semolina yield was greater than that produced by milling uncooled wheat at a normal temperature. The ash figures for the cold-milled and control samples were similar. "Super-cooling" apparently caused some mellowing of the endosperm, although the semolina obtained was relatively tough.

In 1955 Pfister (503) noted that, in comparison with heat treatment of milling stock, cold treatment had received little study and he urged that it be given more attention. After referring to the work of

TABLE 22.--*Crushing gap temperatures and increase of temperature of the millstock (wheat)*

Passage	Temperature difference between air and crushing temperature		Temperature increase of millstock	
	Average	Range	Average	Range
Break System:	°C.	°C.	°C.	°C.
1 break---------------	8.7	6.2-11.5	3.8	2.5-5.2
2 break---------------	8.4	6.0-10.0	2.7	2.0-4.3
3 break---------------	8.7	4.9-12.0	4.8	2.5-7.0
4 break---------------	10.1	6.0-14.5	5.4	4.2-6.5
Bran roll-------------	14.7	13.0-16.7	6.7	5.3-8.1
Reduction:				
Front passage---------	7.8	3.1-16.0	4.8	0.1-11.0
Middle passage--------	14.5	2.4-23.5	7.4	2.2-13.6
Rear passage----------	20.0	9.2-28.0	10.0	2.2-15.5

Source: Pelshenke (486, p. 38, table 1).

Loizillon, he mentioned a cooling method (German Patent No. 672,942) in which wheat was cooled to 3° to 10° C. under vacuum, after which the cooled wheat was sent to the rolls. He did not know whether this method had been used commercially. Pfister considered worthy of investigation the point made by Loizillon that in the usual milling process the later mill streams have a poorer quality of gluten than the early ones, although the opposite should be true. Pfister suggested that the easier separation of bran from endosperm claimed for cold milling might be due to a hardening of the contents of the aleurone cells.

Summary

Most of the data on cold conditioning of wheat may be summarized in a few general statements. The original moisture in the wheat and the relative humidity of the air, rather than the amount of water added in tempering, affected evaporation from the stock during milling (591, 592). Increased moisture content of the stock lowered flour extraction (487, 587, 650), increased the production of bran (487, 587), and saved power consumption (487) during milling on an experimental mill. It also decreased resistance of the kernels to crushing (367), decreased scouring loss (148), increased pearling loss (620), and cut tempering time (35).

The length of temper may, of course, be limited by available bin space. Forty-eight hours was recommended for Manitoba wheat (637) and about 72 hours was reported to give the most break flour from hard wheat (615). In the early part of the century the most frequently used tempering times were from 20 to 30 hours (408, 608). Recently, one writer (43) stated that a minimum of 24 hours' temper is now favored for hard wheats by most United States millers. A shortening of the tempering time by splitting wheat prior to tempering was reported (307). Opinions concerning the effect of increased tempering time on power consumption varied from no effect (615) to a saving of power (413, 608).

The need for separate treatment for wheats of different types and different percentages of vitreous kernels was emphasized (413, 648). Experimental evidence for occurrence of appreciable biochemical changes in wheat during cold conditioning was slight. An increase in reducing sugars and both reduction and increase in catalase activity and diastatic activity were reported (400, 602).

Some additives to tempering water have been claimed to facilitate conditioning without adverse effects on milling or baking characteristics (306, 528, 612).

Recent investigations of problems connected with the milling of cold stock (14, 486, 503, 568) indicate renewed interest in advantages claimed for cold milling. These include improvement in millability and gluten quality and decrease in loss of moisture from stock (317, 318, 398).

WARM CONDITIONING OF WHEAT

Conditioning With Heat at Not Over 115° F.

Effects on millability

The chief advantage claimed for warm conditioning over cold conditioning is that the use of heat cuts the standing time required for penetration of moisture into the grain. Mellowing of hard wheat kernels is largely dependent on the entrance of moisture. From the following data given by Polewka (504), it appears that heat of conditioning facilitates the mellowing process. He determined the texture of the kernels by examining sections with a diaphanoscope. It is inferred from other portions of Polewka's article that washed Manitoba 4 wheat may have been used in this experiment.

	Kernels with specified texture		
	Mellow	Semivitreous	Vitreous
Method of treatment of wheat:			
Dampening in bin for--	*Percent*	*Percent*	*Percent*
24 hours	18	46	36
72 hours	24	56	20
Conditioned in closed circuit drier	46	47	7

Warm conditioning does not eliminate the need for separate preliminary treatment (moistening and holding) of wheats of different character. Brabender and Abdon (100) reported on conditioning mixtures of hard and soft wheats. A mixture containing 45 percent of Manitoba and 55 percent of soft Plate and Russian wheat was washed, held for 8 hours, and conditioned for 75 minutes at 42° C. Farinograms of flour streams showed that the lower breaks and reductions had more Manitoba-like strength than the higher grade streams, thus indicating a fractionation by wheat type. When the Manitoba wheat was tempered and held for 48 hours, the soft wheat tempered and held for 8 hours, and the two then conditioned together for 75 minutes at 42°, the higher grade streams were properly strengthened.

Kent-Jones (354, 357) studied the effects of heat on a number of wheat samples. To four samples of Manitoba wheat of 11.3-percent moisture content, 3.0-, 5.0-, 6.5-, and 8.5-percent water were added, respectively. Dry Persian wheat was dampened with 10-percent water. Two samples of yoeman wheat were used, one at 15.7- and one at 17.7-percent moisture content. The English wheat was left at its natural moisture content of 16.89 percent. The wheat samples were heated at 90°, 110°, and 135° F. for periods of 1 to 24 hours. The wheats were cooled and milled, and tests were made on the flours for ash, soluble extract, soluble phosphorus, maltose, pH, and viscosity of suspensions. At 90° and 110° no appreciable changes in the resultant flours were apparent. Results of the 135° treatment are discussed under hot conditioning, page 30. According to Kent-Jones, the experience of many millers that warm conditioning yields brighter and stronger flour results not from gluten modification but from better endosperm separation that gives flour freer from detrimental branny materials.

Effects on baking quality

Some data concerning the effect of warm conditioning on baking quality have been published. Vermeylen (637) carried on a series of laboratory experiments in conditioning and evaluated the results with the Farinograph. The results of his experiments 1 and 7 on a single lot of Manitoba 2 wheat are given in table 23. Experiment 1 shows that heating the wheat to 40° or 45° C. for 1 hour gave no more improvement in baking quality than holding it for 24 hours without heating. Experiment 7 shows that after the wheat had been moistened and held for 72 hours, it was so sensitive to temperature changes that a rise from 44° to 46° resulted in overconditioning as judged by a decrease in elasticity and consistency.

Losev (400) found that flour from wheat conditioned warm (27° C.) gave

TABLE 23.--*Effect of holding time and temperature of treatment on gluten characteristics as determined by the Farinograph*

Experiment No.	Moisture added	Holding time	Heating		Results
			Temp.	Time	
	Percent	*Hour(s)*	°C.	*Hour(s)*	
1a--------	0	0	---	0	Slow development, immediate weakening.
1b--------	5	24	---	0	Good stability, improved elasticity, rapid development.
1c--------	[1] (5)	0	40	1	Slight general improvement over 1a.
1d--------	(5)	0	45	1	Slightly better than 1c.
7a--------	(5)	48	44	(1.5)	Consistency increases to end of experiment.
7b--------	(5)	48	46	(1.5)	Weakening of gluten.
7c--------	(5)	72	44	(1.5)	Rapid development, perfect stability.
7d--------	(5)	72	46	(1.5)	Overconditioned.

[1] The figures in parentheses are inferred from the text.

Source: Vermeylen (637, pp. 509, 513).

poorer loaves of bread than that from wheat conditioned cold (18°) (see table 18, p. 17).

Remington (523) reported a small increase in the strength figure for warm-conditioned over unconditioned wheat. This strength figure (obtained by the Rapid Standard Process) was increased still more when a few hours of warm standing time were included in the flow (table 24). The hydrolizer process consists of heating, drying, and cooling the grain in a continuous flow of about 50 minutes. In the Paul-Rigg process wheat is washed, whizzed, held for 6 hours, passed through a steam-jacketed cylinder in which it is heated to 100° F., held in the heated state for about 6 hours, cooled, and milled.

TABLE 24.--*Changes in moisture and strength figures for wheats conditioned in a model hydrolizer and by a modification of the Paul-Rigg process*

Wheat	Type of conditioning	Moisture content				Strength figure	
		Before conditioning	After conditioning	To 1 Break	In flour	Unconditioned	Conditioned
		Percent	*Percent*	*Percent*	*Percent*		
Manitoba 1-----	Hyd.	10.65	16.87	16.62	14.98	94	95
	P-R	10.65	17.12	16.82	15.24	94	98
Australian-----	Hyd.	10.21	16.44	16.15	15.21	64	66
	P-R	10.21	16.81	16.62	15.24	64	67
English--------	Hyd.	19.32	17.72	17.31	16.42	51	53
	P-R	19.32	17.65	16.93	15.94	51	57

Source: Remington (523, p. 204).

Hartkopf (301) gave specific recommendations for warm conditioning three different wheats that showed too long a dough development. All wheats were conditioned for 1.5 hours at 40° C. and held for 6 hours before milling. During the 6 hours the wheat with slow dough development was held at about 30°. By varying the preliminary tempering he shortened their development times to approximately equal values without decreasing their stability. His data are presented in table 25.

Economic aspects

Some observations of two other millers concerning warm conditioning are summarized in table 26. In their discussions both millers pointed out that best results can be obtained only by conditioning different kinds of wheat separately.

Grosse (284) made a comparative study of the yield and market value of the products from the milling of unconditioned wheat and conditioned wheat. Average values from three different millings of a mixture containing 75 percent of hard wheat and 25 percent of domestic wheat were as follows:

	Price per 100 kg., RM[1]	Without conditioner		With conditioner	
		Yield	Value, RM	Yield	Value, RM
Sample:		*Percent*		*Percent*	
Flour, Type 00..........	40	18.79	7.52	24.88	9.95
Flour, Type 0...........	35	48.12	16.84	45.43	15.90
Bread flour..............	25	11.69	2.92	10.21	2.55
Red dog...................	16	6.37	1.02	4.36	.70
Shorts.....................	12	9.56	1.15	14.03	1.68
Bran.......................	11	7.65	.84	2.39	.26
		102.18	30.29	101.30	31.04

---

[1] 1929 values in Reichsmarks.

TABLE 25.--*Procedures for conditioning wheat to shorten the development time of dough*

Wheat characteristic	Initial moisture content	Successive moisture additions and holding periods		Comments
		Water	Time	
	Percent	*Percent*	*Hour(s)*	
Quick dough development.	12	2	12	Development time shortened, stability maintained.
		4, in washer	0	
Medium dough development.	12	2	12	Development time shortened to equal first sample, stability maintained.
		2	12	
		4, in washer	0	
Slow dough development.	12	2	24	Development time shortened to equal first sample, stability maintained.
		2	12	
		2	12	
		3, in washer	0	

Source: Hartkopf (301, p. 57, chart 6).

TABLE 26.--*Observations on warm conditioning in two commercial mills*

Location and wheat	Initial moisture	Moisture added	Holding period	Conditioning		Holding period	Comments
				Temperature	Time		
	Percent	*Percent*	*Hour*	°C.	*Minutes*	*Hours*	
Yugoslavia:[1]							
Hard	8-10	6-8	0	36-38	---	12-19	Flour quality excellent. Daily output increased 15-20 percent. Electric power consumption decreased.
Tunis:[2]							
Mixture:	---	6	0	40-43	70	24 (sent to mill at 16-percent moisture content)	Method gives good millability and high yield of 79 percent flour of good baking quality. Total yield 103.4 percent.
Manitoba	12.2						
Jugo-Theis	14.0						
Hungarian	14.5						
Average	13.6						

Source: [1] Peternel (496).
[2] J. G. (228).

Grosse stated that even if the 0.75 RM profit from use of a conditioner, as calculated by him, was somewhat high, at least a gain of 0.5 to 0.6 RM would be easily made. If the mixture contained only 50 to 60 percent hard wheat an additional profit of 0.25 RM should be gained.

Warm Milling

Temperature of grain at the first break has a very definite effect on the way the grain fractures. Some experiments have been conducted to determine whether benefits can be obtained by milling warm wheat (warm milling).

Anderson (35) milled Turkey variety wheat of the 1936 crop at three temperatures. The grain was tempered from its original moisture of 10.3 percent to 16 percent and was held for different periods of time at 50°, 75°, and 100° F. Portions were milled once through corrugated rolls and sifted through No. 20 W cloth to determine the percentage break extraction. The results presented in table 27 show the increased break release at higher temperatures of milling.

TABLE 27.--*Break extraction as affected by the temperature of tempering and milling and by the tempering time*

Temperature of tempering and milling, °F.	Break extraction after tempering for--						
	1 hour	3 hours	24 hours	40 hours	63 hours	88 hours	125 hours
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
50----------------	12.5	16.4	23.5	23.5	24.7	23.0	21.5
75----------------	18.5	21.5	22.5	24.5	24.8	24.7	24.2
100---------------	21.0	23.0	26.5	24.3	25.5	29.5	27.0

Source: Anderson (35, p. 797, table IV).

Sugden (611) reported experiments of the Research Association of British Flour Millers on the milling of wheat at different temperatures. After preliminary experiments Manitoba wheat previously cold-tempered to 16.5-percent moisture content was milled with both rolls and grain at a series of temperatures ranging from 21° to 54° C. Immediately before milling the grain was warmed to the required temperature by heating it for 30 minutes without moisture change. Some of the results are shown in tables 28 and 29.

Sugden's conclusions were that as the milling temperature is increased to 54° C.--

The quantity of bran increases.

The size of the bran increases.

The quantity of break flour increases.

The quantity of semolina decreases.

The percentage of flour released from middlings and dunst increases.

Ash content and color of flour improve up to a temperature of about 43°C.

Extraction increases by at least 1 percent.

He also concluded that for Manitoba wheat milled at 16.5-percent moisture content, the best temperature was 32° to 38°. Although tables 28 and 29 show that advantages may be obtained by heating to 54°, Kent and others (352), describing these experiments, stated that above 38° it became more difficult to clean up the bran and there seemed to be no advantage in raising the temperature above about 40°.

Further experiments showed that similar results were also obtained on wheat tempered to only 14.5-percent moisture content.

Sugden (611) also reported results of commercial trials that were made in a mill equipped with pneumatic conveying. The grist consisted of 50 percent Manitoba, 30 percent hard winter, and 20 percent English wheat. The hard wheat had been

TABLE 28.--*Effect of warm milling on yield of bran and yield and ash of semolina and flour from the first three breaks*

Temperature of wheat and rolls, °C	Bran		Semolina		Break flour		
	Yield over 24 W	Yield over 7 W	Yield	Ash content	Yield	Ash content	Grade color value
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
21-----------------	14.8	4.8	49.1	0.76	17.7	0.64	9.0
27-----------------	15.1	7.2	47.7	.71	17.8	.59	8.5
32-----------------	15.3	7.9	47.3	.73	18.3	.59	8.5
38-----------------	15.4	8.7	46.6	.70	18.5	.54	8.2
43-----------------	16.5	10.9	45.3	.67	19.0	.52	7.8
49-----------------	17.0	12.2	43.8	.68	19.8	.50	7.7
54-----------------	17.0	13.1	43.5	.71	21.5	---	---

Source: Sugden (611, p. 96, table 5).

TABLE 29.--*Effect of warm milling on straight run flour*

Temperature of wheat and rolls, °C	Yield	Moisture content	Ash content	Grade color value	Release of flour from midds-dunst
	Percent	*Percent*	*Percent*		*Percent*
21-----------------	69.3	15.3	0.45	5.2	90.5
32-----------------	70.4	---	.43	4.9	91.5
38[1]----------------	70.5	---	.44	4.8	91.8
43-----------------	70.0	---	.42	4.6	91.2
54-----------------	71.0	14.9	.42	4.75	92.3

[1] Printed as 33° in journal; apparent from text that this is a misprint.

Source: Sugden (611, p. 98, table 6).

conditioned in a Stabilisor at 54° C. and cooled in the washer in the normal way. A portion of the wheat mixture was milled at room temperature (25°) for a cold-milled control. For warm milling the wheat was heated to a temperature of 38° to 41° by means of a radiator conditioner section above the first break rolls. Warm milling produced less improvement in the yield and color of straight-run flour than had been obtained in the laboratory experiments. Flour extraction was 80.5 percent and the color grade was 6.3 after cold milling. Comparable figures after warm milling were 80.8 and 6.1.

Other improvements found in the laboratory experiments such as larger break chop, more friable endosperm, and easier grinding were apparent in the commercial test.

Further laboratory tests, using a grist containing 80 percent of Manitoba and 20 percent of English wheat, were made to determine whether the use of "Stabilised" wheat as a cold-milled control was responsible for the relatively slight improvement in yield and color of straight-run flour obtained in the commercial trial. Results indicated that the meagerness of improvement could not be attributed to the use of "Stabilised" wheat.

Limited commercial experience reported by Kent et al. (352) indicates the desirability of putting wheat to the first break at 38° to 41° C. in installations where pneumatic conveying provides a cooling effect on stocks after the first break; thereby difficulties in sifting hot stocks are avoided.

Kent and others stated that laboratory tests of straight-run flour indicated that warm milling had no significant effect on physical properties of the dough nor on loaf volume. With warm milling, color and grain of crumb showed improvement when the baking test was carried out without chemical improvers. No improvement could be seen, however, when 10 or 15 p.p.m. of bromate was used.

Summary

Data on warm conditioning of wheat show that, for the most part, warm conditioning gave as good or slightly better results than cold conditioning with respect to profit (in 1929), millability, and quality of flour produced. The need for pretreating wheat (tempering) in a way suited to its particular type was stressed.

Laboratory experiments indicated that warming the stock increased the break release (35, 611) and increased the size and the quantity of bran and total yield of flour (611). Improvements were not so great with some commercial trials (611), but warm milling has been recommended for installations that have pneumatic conveying (352).

HOT CONDITIONING OF WHEAT

Conditioning With Heat at Temperatures Above 115° F.

Hot conditioning of wheat, like warm conditioning, hastens the penetration of water into the wheat kernel and the attainment of a uniform distribution of moisture. Use of temperatures above 46° C. may also bring about biochemical and physical changes in the constituents of the grain. Some of these changes may materially affect baking quality.

Early studies on Kansas hard wheat

One of the earliest reports on the effect of high temperatures is that of Swanson and others (624). They undertook to determine whether the improvements accompanying the aging or "sweating" of Kansas hard wheat immediately after harvest could be achieved by moistening and heating the wheat. In 1911 they used three temperatures, 45°, 70°, and 98° C., three quantities of water, 25, 50, and 100 cc. per kg. wheat, and four different times (various) of treatment at each temperature, thus giving 36 samples in all. All samples milled like normal wheats. A temperature of 45° did not improve the baking quality; 98° was harmful. Eleven minutes was the shortest time of treatment at the latter temperature. At 98° and also at 70°, when 100 cc. of water were added, there was an increase in amino acids proportional to the time the wheat was treated and a reduction in gluten quality. The best loaves were obtained from samples heated to 70° with 25 cc. of water for 12 to 24 hours and with 50 cc. of water for 3 hours.

In 1912 further experiments were conducted, using temperatures of 50°, 60°, 70°, and 88° C. for various lengths of time on Kansas hard wheat previously moistened to 13.5 percent. The best loaves, judged by volume and texture, were obtained from wheat heated at 88° for 3 to 12 minutes Only the data for temperatures 70° and 88° are given here (table 30). Data for 50° and 60° were not greatly different from those for 70°. Swanson concluded that heat, especially when applied to new wheat, can improve the milling quality of wheat and the baking qualities of the flour.

TABLE 30.--*Baking tests of flours from wheat tempered to 13.5-percent moisture content and heated*

Temperature, °C. and duration	Loaf volume	Evenness of texture, 100=perfection	Thinness of wall, 100=perfection
Hours at 70°:	*Cc.*		
1------------	1,820	94	92
2------------	1,770	94	92
3------------	1,870	94	93
4------------	1,810	94	93
5------------	1,590	90	90
6------------	1,740	94	94
Minutes at 88°:			
3------------	1,910	96	96
6------------	1,920	96	96
9------------	1,900	99	100
12------------	1,830	100	99
15------------	1,820	98	96
18------------	1,800	98	94

Source: Swanson and others (624, p. 45, table XIX).

Biochemical effects

Investigations emphasizing biochemical changes occurring in wheat during hot conditioning were reported by Sosedov and others (602), Rohrlich and Brückner (534), and Costa (142). Sosedov and others studied the effects of heat on four kinds of wheat and since each kind was given a different treatment as to time or temperature, individual effects of these factors cannot be distinguished (table 31). Control samples were milled at their natural moisture. Heated samples were brought to a moisture content of 16.5 to 17 percent, heated the specified time with constant mixing, cooled, and held for 4 to 5 hours before being milled. In all four kinds of wheat total sugars were increased and diastatic activity was reduced or increased depending on the method of analysis.

Rohrlich and Brückner (534) studied the effect on enzyme activity of drying samples of German soft wheat that had been tempered to different moistures. The samples were dried with hot air at various temperatures for 1 hour after an equilibration period of 15 minutes. Data on the enzyme activity in flour from the different samples are given in table 32. Catalase was stable with treatment up to 65° C., but its activity decreased rapidly with higher temperatures. The authors called attention to the 36-and 38-percent decrease of maltose in grain of 15- and 18-percent moisture content that was dried at 40° C. and to the decrease of proteinase above 65°.

Costa (142), whose data are not presented here because his exact methods of conditioning were not reported, found an increase in glucose and a slight decrease in fat after conditioning wheat at temperatures between 40° and 60° C.

Effects on Baking Quality

In 1926 Kent-Jones (353, 354, 357) studied the effect of heat on several kinds of wheat, determining its effect by chemical analysis and baking tests of the flour. Under the conditions of his experiments, holding damped wheat for 24 hours at 110° F. produced no changes in chemical properties or baking quality. When the wheat was heated to 135° no chemical or physical changes were observed after 2 hours but slight chemical changes occurred after 6 hours. After heating was extended to 24 hours the flour was greatly increased in strength, but it developed sour odors on standing for a few hours.

To study the effect on wheat of heat alone, rather than heat and moisture, Kent-Jones subjected air-dry wheat to 160° F. for 1.5 to 2 hours before the subsequent conditioning. Flour from this wheat had increased strength. The use of this method of treatment of wheat in a mill led to experiments with heating flours. Strongly heated flour (180° for 10 to 12 hours) added at the rate of 0.7 percent to untreated flour strengthened the baking quality in a manner similar to hot treatment of the wheat.

Geddes (233), Lindberg (388), and Becker and Sallans (64) investigated the interrelationship between temperature of treatment, time of treatment, and moisture of the grain

TABLE 31.--*Biochemical analyses and baking characteristics of unheated and heated wheat*

Characteristics studied	Wheat and treatment							
	Novokreimka		Tsezium		Gostianum		Koopbratorka	
	Control	Heated at 55° for 45 min.	Control	Heated at 55° for 35 min.	Control	Heated at 50° for 40 min.	Control	Heated at 45° for 40 min.
Vitreous kernels-------percent--	6.50	6.50	97.0	97.0	58.9	58.9	54.6	54.6
Moisture-----------------do----	11.5	15.3	12.7	14.4	11.5	15.8	11.7	15.0
Gluten:								
Wet---------------------do----	19.44	18.80	39.70	38.10	33.90	32.48	21.56	20.24
Dry---------------------do----	6.60	6.32	12.7	12.7	10.7	11.1	7.12	6.68
Swelling No.------------------	13.6	12.8	22.6	22.0	16.6	17.2	12.3	15.7
pH------------------------------	6.32	6.53	6.64	6.35	6.23	6.59	6.36	6.53
Soluble carbohydrates:								
Reducing (Bertram)------do----	.20	.26	.25	.26	.20	.22	.21	.22
Reducing (Issekut)-------mg.--	34.12	41.06	41.93	45.67	34.46	41.30	47.28	48.76
Fructose-------------percent--	2.88	2.73	3.33	3.26	2.60	2.53	3.26	3.11
Maltose----------------do-----	1.38	1.40	1.37	1.26	1.12	1.07	1.12	1.30
Diastatic activity:								
Rumsey method-----------------	226.3	152.0	204.1	173.0	146.8	137.1	251.9	168.9
Sosedov method----------------	531.8	621.6	611.8	624.0	530.0	573.2	531.6	588.1
Catalase activity, ml. N/10 $KMnO_4$------------------------	27.2	28.7	38.9	38.5	27.4	28.5	27.4	28.8
Alveograph data:								
Stiffness, "P"---------------	73.0	91.1	99.3	125.0	90.6	84.4	97.0	87.5
Extensibility, "G"------------	24.8	16.5	20.3	19.0	24.6	25.5	16.6	18.8
Work, "W", ergs---------------	261	170	254	313	297	283	172	162
Baking characteristics:								
H:d---------------------------	.37	.37	.42	.48	.38	.38	.32	.46
Volume------------------------	384	354	374	408	410	324	399	384
Texture-----------------------	Fine, even	Fine, uneven	Fine, quite even	Fine, even, thick wall	Fine, even	Even	Fine, even	Fine, even.
Crumb quality-----------------	Elastic, resilient	Same	Same	Same	Same	Same	Very elastic	Elastic.

Source: Sosedov and others (602, pp. 876-877).

as evaluated by baking quality. Geddes (233) rated results of his studies by means of a "single figure estimate" of breads baked by the basic formula without bromate and with 0.001-percent $KBrO_3$ added. Table 33 shows clearly the effects on baking

TABLE 32.--*Effect on the flour enzymes of drying wheat for 1 hour at various temperatures*[1]

Grain moisture and temperature, °C.	Flour		Catalase ml. O_2	β-Amylase maltose, % at		Proteinase
	Ash	H_2O		27° C.	62° C.	
Grain moisture:						
a. 15 percent:	*Percent*	*Percent*		*Percent*	*Percent*	*Mg.% amino-N*
20--------	0.80	12.6	19.8	3.3	50	23.8
40--------	.73	12.3	---	2.1	53	23.8
55--------	.74	11.2	15.4	3.0	51	18.2
65--------	.75	10.2	15.4	2.3	51	18.2
80--------	.76	8.9	11.3	2.2	50	16.8
100--------	.81	7.6	5.6	2.0	48	14.4
b. 18 percent:						
20--------	.74	---	17.3	2.6	52	21.0
40--------	.81	14.1	17.5	1.6	51	21.0
55--------	.70	12.5	17.3	1.9	49	18.2
65--------	.72	11.9	18.5	2.0	50	16.8
80--------	.72	10.2	13.6	1.8	49	16.8
100--------	.72	8.4	6.8	1.4	46	15.4
c. 20 percent:						
20--------	.71	14.3	23.8	1.7	49	21.0
40--------	.76	13.3	23.9	2.0	49	22.4
65--------	.74	13.6	24.6	1.7	49	---
100--------	.74	10.5	8.4	1.6	49	16.8
d. 22 percent:						
20--------	.67	---	9.4 [sic]	1.6	50	18.2
40--------	.66	13.5	---	1.6	51	16.8
65--------	.68	13.5	18.5	1.6	53	15.4
100--------	.71	11.3	12.6	1.6	49	15.4

[1] All values are on dry basis.

Source: Rohrlich and Brückner (534, pp. 13-14, table 1).

quality of varying heat and moisture content at time of treatment. The critical temperature which brought about a sharp drop in baking quality was lowered by an increase in moisture content of the wheat. The highest baking scores were found in the controls of the bromate method. The very low baking quality of flour from wheat treated at the highest temperature and baked by the bromate method can be interpreted as the result of an additive effect of heat and bromate.

Lindberg (388), using Swedish wheat samples that ranged in moisture content from 13 to 33 percent, varied the temperature from 30° to 70° C. and the time of treatment from 1 to 120 minutes. The effect was judged by loaf volume, certain flour characteristics, and viability of grain. He

TABLE 33.--*Baking quality of flours made by two formulas from hard red spring wheat heated for 3 hours, as affected by moisture content of wheat and temperature of treatment*

Treatment, °F.	Basic formula: no $KBrO_3$				Basic formula plus 0.001% $KBrO_3$			
	Moisture in wheat --				Moisture in wheat --			
	15.64 percent	16.72 percent	19.94 percent	21.62 percent	15.64 percent	16.72 percent	19.94 percent	21.62 percent
	Score	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*	*Score*
Control----------	89	92	101	102	99	103	110	108
130------------	---	---	103	99	---	---	107	89
140------------	92	91	88	70	100	99	78	64
150------------	90	92	47	25	96	94	31	27
160------------	86	53	---	---	74	38	---	---

Source: Geddes (233, p. 554, table X).

found that the critical temperature at which bread volume was decreased when no bromate was used was 50° C. for 25-percent, 55° for 20-percent, and 65° for 15-percent moisture content. These results agree quite closely with those of Geddes (233). Lindberg found that the use of bromate (0.002-0.003 percent) lowered the critical temperature by 5° to 10°. The results of Geddes (table 33), on the other hand, merely showed a greater drop in bread volume when bromate was used.

Becker and Sallans (64), using Thatcher hard red spring wheat and the same general method as Geddes, investigated the effect on loaf volume of varying the treatment temperature of wheat samples of 8-, 10-, 12-, and 16-percent moisture content. It can be seen from table 34, in which their results are given, that the temperature which brought about a drop in loaf volume of about 50 percent decreased with an increase in moisture content of the wheat.

According to Ward (647), wheats of low stability can be improved by heat. He gave data to illustrate the effect of 110° and 150° F. on Russian, Plate, and English wheats (table 35). Unfortunately he did not state either the moisture content of the wheat, the time of heating, or the methods by which the figures were obtained.

Ward presented his data concerning the effect of hot conditioning of wheats on the baking quality of flour mixtures by photographs of the loaves. From baking tests he concluded that flour from Plate and Russian wheats conditioned at 160° F. could carry 10 percent and 20 percent, respectively,

TABLE 34.--*Effect on loaf volume of wheat moisture and the temperature and time of treatment*

Moisture (wet basis) %	Temperature		Time	Loaf volume[1]	V[2]
	°F.	*°C.*	*Hrs.*	*Cc.*	
16.1----	Control	-	0	970	1.000
	145	63	3	895	.922
	150	66	3	690	.711
	160	71	2	465	.480
	170	77	2	255	.263
	175	80	2	290	.299
12.1	Control	-	0	950	1.000
	165	74	3	802	.845
	170	77	3	707	.745
	180	82	2	467	.492
	185	85	2	300	.316
	190	88	2	200	.295
10.3	Control	-	0	930	1.000
	170	77	3	890	.937
	175	80	3	890	.937
	180	82	2	860	.905
	190	88	2	545	.574
	195	91	2	410	.432
8.0	Control	-	0	905	1.000
	190	88	3	890	.984
	195	91	3	850	.940
	205	96	2	820	.906
	210	99	2	775	.856
	215	102	2	605	.668

[1] Basic formula + 0.001 percent bromate.

[2] V = ratio between the final and the initial loaf volume.

Source: Becker and Sallans (64, p. 257, table 1).

TABLE 35.--*Strength properties of wheats as affected by treatment at moderate and elevated temperatures*

Properties	Russian wheat treated at--			Plate wheat treated at--			English wheat treated at--		
	Cold	110° F.	150° F.	Cold	110° F.	150° F.	Cold	110° F.	150° F.
Extensibility------	16.0	16.0	13.0	9.5	9.5	8.5	8.5	8.5	8.0
Viscosity----------	6.0	6.0	7.0	7.0	7.0	8.5	5.0	5.5	6.5
Stability----------	2.0	3.0	6.0	6.0	6.5	8.5	1.0	1.0	7.0
Resiliency---------	10.0	10.0	11.5	8.0	8.5	9.5	6.0	6.0	7.5
Gas production-----	10.0	10.0	9.0	5.5	5.5	4.5	5.5	5.5	4.0
Maltose figure---	1.8	1.77	1.6	1.27	1.23	1.13	1.27	1.23	1.08
Water absorption-	13.8	14.0	14.9	14.7	14.8	15.7	12.9	12.9	14.2

Source: Ward (647, pp. 13-14).

more flour of cold-conditioned English wheat than if the former wheats had been only cold-conditioned. More flour of English wheat could be blended with flour from Manitoba wheat if some of the English wheat was conditioned at 160° F. rather than cold-conditioned.

In 1950 Wild (652) published the results of three of a longer series of experimental conditioning tests designed to show the effect of heat on the baking quality of flours from German soft wheats. The flours used for laboratory and baking tests were milled to 70 percent extraction after the wheats had been stored for 24 hours. The approximate moisture content of the grain at the first break was 16.5 percent. Flour was stored for 8 days before the baking tests were run. All three series showed that a temperature of 50° to 57° C. for 1.25 to 1.5 hours with a moisture addition of 5 to 6 percent (used as a substitute for the washer) gave the best conditions for improvement of baking quality. Pertinent data from Series I are given in table 36. An increase in the moisture added and the temperature of the treatment did not greatly affect the amount of gluten separable from the flour but gradually raised the swelling number and reduced the maltose figure. It is apparent from the baking tests that, when no additives were used, treatment at 50° or 57° C. (No. 4, 5) gave the most improvement in baking quality. With the addition of chemicals, tearing of the dough occurred after treatment at 57°. Protein in the flour averaged 12.1 percent with only slight variations. Dough yield was also quite uniform; it varied from 162.5 to 163.5. The porosity number was 8 for the control and treatments at lower temperatures and 8 to 9 for treatments above 50°.

Effects on physical properties of gluten and dough

Vermeylen (637), whose series of laboratory experiments on conditioning have been referred to previously (cold conditioning, p. 13), treated grain at temperatures ranging from 50° to 60° C. The effects of certain experimental conditions on Farinograph curves are given in table 37.

Treatment at 55° C. (2c) gave the most improvement and 60° brought about overconditioning. Vermeylen did not comment on the fact that 52° resulted in overconditioning in experiment 6c. Rapid cooling of the grain after the heating period was needed to terminate the treatment at a specified time (2a, b, d, e). A longer holding time without heat gave adequate improvement (4b, c) or an improvement equal to that of a shorter holding time plus heat (5c, d). Results of experiments presented in tables 37 and 38 show that different grades and different lots of wheats differ in their response to heat. Vermeylen pointed out that Manitoba 4, lots a and b, should not have been heated, whereas Manitoba 2 and Manitoba 5 were improved by heat.

Kühl (378) reported on the effects of heat on two slightly different lots of German domestic wheat which had been soaked for 4 hours and held overnight. The characteristics of gluten from break flours of untreated and treated wheats are given in table 39. It should be noted that Kühl was

TABLE 36.--*Analyses and evaluations of flour from wheat conditioned for 1.5 hours in an experimental conditioner*

Analyses of flour

Test No.	Temperature	Water added	Ash	Gluten separable from flour	Swelling No.	Maltose No. (Lane and Eynon) 1 hour at 27° C.
	°C.	*Percent*	*Percent*			
1	---	1.5	0.55	39.70	1.0	1.04
2	36	3.5	.57	39.70	2.5	1.02
3	43	4.5	.57	39.75	5.5	.98
4	50	6	.55	39.80	10.5	.95
5	57	7	.54	39.65	16.5	.92
6	63	7.5	.57	39.30	19.0	.87

Baking tests: (a) without and (b) with chemical additives.[1]

Test No.	Loaf volume	Fermentation	Loaf stand	Dough properties
1a	500	Difficult	Flat	Tends to run.
1b	650	Sluggish	Satisfactory	Softens somewhat, subsequently.
2a	510	Difficult	Flat	Tends to run.
2b	658	Sluggish	Satisfactory	Softens somewhat, subsequently.
3a	525	Difficult	Satisfactory	Tends to run at end of fermentation.
3b	670	Good	Good	Good and woolly.
4a	539	Somewhat difficult	Good	Good.
4b	685	Very good	Good and round	Good and woolly.
5a	530	Somewhat difficult	Good	Good.
5b	675	Very good	Good, round	Tends to tear, somewhat torn.
6a	490	Very good	Firm at end of fermentation	Typically overconditioned.
6b	510	Good	Firm at end of fermentation	Completely torn.

[1] 1.5 g. bromate, 16 g. persulfate, and 0.6 percent malt added per sack of flour.

Source: Wild (652, p. 493, series I).

apparently using wheats whose gluten lacked extensibility. He found that heat treatment up to 62° to 65° C. improved the gluten by increasing its extensibility and elasticity. The mixing of 5 percent of heated wheat with unconditioned wheat (experiments 1c, 2b) yielded flour with gluten of better quality than the control but not so good as that of the wheat heated to 62° to 65°.

Ziegler (666), too, worked with wheats which were somewhat lacking in extensibility. He demonstrated with the Extensimeter an increase in extensibility of the dough after treatment in a hot-air conditioner. The maximum increase in extensibility (G, table 40) was found at 49° C. for Manitoba and at 47° for Swiss domestic wheat. Higher temperatures brought about a reduction in extensibility. The treatment giving maximum extensibility also yielded the highest baking number.

Lockwood (393) recommended use of an Extensigraph for the determination of the optimum time and temperature of

TABLE 37. -- *Effect of holding time, temperature, and rate of cooling on gluten characteristics of one lot of Manitoba 2 wheat as determined by the Farinograph*

Experiment No.	Moisture added	Holding time	Heating of samples: Temperature	Heating of samples: Time	Cooling	Results
	Percent	*Hours*	^{o}C.	*Hour(s)*		
1b, control	5	24	None	---	---	Dough formation rapid, good stability.
2a---------	5	24	50	1.5	Rapid	Dough formation too slow.
2b---------	5	24	50	1.5	Slow	Dough formation very rapid, weakening.
2c---------	5	24	55	1.5	---	Dough formation improved, elasticity increased.
2d---------	5	24	60	1.5	Rapid	Overconditioned.
2e---------	5	24	60	1.5	Slow	More overconditioned.
6c---------	5	24	52	1.5	Rapid	Overconditioned.
1a, control	0	0	None	---	---	Slow development, immediate weakening.
4b---------	5	48	55	1	---	General improvement.
4c---------	5	72	None	---	---	Improved, elastic, weakens.
5c---------	[1] (5)	24	50	1.5	---	General improvement.
5d---------	(5)	48	None	---	---	General improvement.

[1] Figures in parentheses are not stated but are inferred from the text.

Source: Vermeylen (637, pp. 509-512).

conditioning. Data presented in table 41 show the possibilities for improvement of different types of wheat by hot conditioning. These wheats, in contrast with those used by Kühl and Ziegler, were overextensible and could be improved by decreasing their extensibility.

Extensive studies reported by Michelli (422) showed that laboratory studies have direct value for commercial application. A particular effort was made to simulate the commercial process by slow warming and cooling. Table 42 shows the close agreement of Alveograph values between experimental and commercial results.

Other laboratory conditioning experiments reported by Michelli include studies of effects of altering the holding period after conditioning and cooling, the time of treatment, and the temperature (table 43). A 10-minute recooling period to 20° or 22° C. was always used after the treatment. Michelli concluded that preliminary runs with a laboratory conditioner would provide a reliable basis for conditioning on a commercial scale.

Gehle (255) evaluated in the laboratory the effects of heat on the baking quality of commercial lots of wheat from three districts of Germany. The wheats were conditioned in a Miag laboratory conditioner, which simulates commercial radiator conditioning, and milled in a Miag laboratory mill. Farinograph, Extensigraph, and baking tests were applied. Characteristics of the three lots were as follows (see p. 40):

TABLE 38. -- *Effect of holding time and temperature of treatment on gluten characteristics of different lots of wheat as indicated by farinograms*

Wheat and experiment No.	Moisture added	Holding time	Heating of samples		Results
			Temperature	Time	
Manitoba 4:					
Lot a:	*Percent*	*Hours*	°C.	*Hour(s)*	
10a-------	0	0	None	0	Dough formation difficult, weakening.
10b-------	[1] (5)	24	None	0	Improved stability.
10c-------	(5)	72	None	0	General improvement.
10d-------	(5)	72	48	1	Poorer than 10c.
Lot b:					
11a-------	0	0	None	0	Great elasticity.
11b-------	(5)	72	None	0	Great improvement.
11c-------	(5)	72	45	1.5	Overconditioned.
11d-------	(5)	72	50	1.5	Pronounced overconditioning.
Manitoba 5:					
14a-------	0	0	None	0	Consistency increases.
14b-------	5	24	55	1.5	Perfect curve.

[1] Figures in parentheses are not stated but are inferred from text.

Source: Vermeylen (637, pp. 515-518).

TABLE 39. -- *Effect of heat on the gluten of soaked German domestic wheat*

Experiment	Time	Incubator temperature	Wet gluten	Extensibility No.[1]	Elasticity No.[2]
	Hour(s)	°C.	*Percent*		
1 Untreated----------------	0	---	24.84	4	62.5
1a-------------------------	1	62	25.26	7	64.3
1b-------------------------	2	70-73	Could not wash out gluten.		
1c (5% 1b. + 95% 1)[3]--------	0	---	25.20	5.1	70.0
2 Untreated----------------	0	---	23.75	5	50.0
2a-------------------------	2	65	23.75	9	55.6
2b (5% 2a + 95% 2)[3]---------	0	---	---	7.5	53.3
2c-------------------------	1.5	[4] 85	Could not wash out gluten.		

[1] Extensibility No. = Extension in cm. to near breaking point of a piece of gluten 3 x 6 x 9 mm.

[2] Elasticity No. = Difference in cm. between the extended and the relaxed gluten string, expressed as a percentage of the Extensibility No.

[3] 5 percent treated and 95 percent untreated wheats mixed and milled.

[4] Wheat attained 65° by the end of 1 hour and 70° after 1.5 hour.

Source: Kühl (378, p. 471).

TABLE 40.--*Dough tests and baking results of flours from two wheats conditioned with hot air at various temperatures*

Wheat and temperature, °C.	Extensimeter[1]			Wet gluten, %	Swelling No.	Baking No.
	P	G	W			
Manitoba:						
Control-------------------	81	16	176	30.5	21	117
43-----------------------	92	17	220	32.4	22.5	---
49-----------------------	56	19	174	30.1	23	181
52-----------------------	64	17	152	26.8	31	137
Swiss domestic:						
Control-------------------	66	17	144	28.5	17.5	106
42-----------------------	63	18	158	30.7	16.5	126
47-----------------------	62	19	174	30.0	18.5	132
52-----------------------	76	16	167	30.3	18.0	119
55-----------------------	81	14	141	29.0	19.0	74

[1] P = height at peak of curve; G = volume, measuring extensibility; and W = ergs of work done in blowing the bubble.

Source: Ziegler (666, pp. 1,037-1,038, figs. 1,2).

TABLE 41.-- *Extensigraph data for hot-conditioned wheats*

Wheat and treatment	Area	Resistance	Extension
Sabanero, 18.5% moisture:			
Control--------------------------------	40	120	21.5
Heated to 145° F., held 30 min.-------	74	370	13
Heated to 145° F., held 60 min.-------	86	595	10.25
Barusso, 18.0% moisture:			
Control--------------------------------	81	195	22
To 170° F., cooled immediately--------	142	730	12.25
Baril Plate:			
Control--------------------------------	99	215	22.75
To 170° F., cooled immediately--------	126	590	13.25
No. 1 Manitoba:			
Control--------------------------------	88	210	20.75
To 153° F., cooled immediately--------	129	440	16
English (Red Standard):			
Control--------------------------------	14	85	12
To 168° F., cooled immediately--------	29	255	7.75
Uruguay:			
Control--------------------------------	52	160	20.5
To 142° F., cooled immediately--------	82	460	13.25

Source: Lockwood (393, pp. 207-212).

Test	Magdeburg	Saale	East Prussia
Moisture............percent..	15.6	16.6	14.0
Hectoliter weight.........kilograms..	81.7	79.9	78.1
Protein (d.b.)..............percent..	12.5	12.4	10.6
Meal fermentation test...............minutes..	41	40	46

Among the numerous tests and observations recorded, only those given in table 44 showed appreciable differences. Although the results show some inconsistencies, in general, baking quality was improved by the use of heat.

Data from commercial mills

Dalibor (145) checked the passages of a wheat mill each month for yield, ash content, gluten content, and swelling number of gluten. Baking tests were also made. Since only portions of the data were published, the basis for his conclusion that conditioning as done at that time did not influence baking quality, is not known. Some statements of the conditioning temperatures and the yield in different seasons under uniform roll settings are tabulated below:

	Conditioning temperature	Flour yield
Time:	*°C.*	*Percent*
1937		
September.........................	50	80.2
1938		
February..........................	58	82.5
March.............................	55	81.2
April...............................	54	81.5
May................................	46	79.8
Unconditioned run..............	--	70.0

Time of conditioning grain at the above temperatures was 2.25 hours with moisture content at 19 percent. Yield was affected favorably by increasing the conditioning temperature. The high yield at 58° C. was accompanied by a rise in ash

TABLE 42. --*Results obtained by conditioning wheat with (a) a laboratory conditioner and with (b) an industrial conditioner*

Wheat and conditions of treatment		Flour moisture	Alveograph[1]			Extraction	Dry gluten	Water absorption
			P	G	W			
Manitoba 2 Atlantic:		*Percent*				*Percent*	*Percent*	*Percent*
15' to 42° C., 30' at 50°, 10' recooling at 22°, held 20 hours.	(a)--	14.4	125	22.8	489	67.8	14.1	67
	(b)--	14.3	120	23	470	66	13.8	66
Heavy Northern Spring I:								
10' to 42°, 35' at 50°, 10' recooling to 22°, held 24 hours.	(a)--	14.3	97	20.3	309.4	67.5	10.6	68.6
	(b)--	14.9	94	20	292	66	13	70
Hard Winter II:								
15' to 42°, 30' at 49°, 10' recooling to 22°, held 20 hours.	(a)--	14.7	65	22.8	247	67	10	65.3
	(b)--	14.6	71	21.7	256	65.7	11	64
Soft White 3 Atlantic:								
10' to 45°, 20' at 55°, 10' recooling to 21° C., held 18 hours.	(a)--	13.2	54	19	143	65	7	55.3
	(b)--	14.2	47	19.7	131	62	6	56

[1] P = height at peak of curve; G = volume, measuring extensibility; and W = ergs of work done in blowing the bubble.

Source: Michelli (422, pp. 120-121, Table I).

TABLE 43.--*Some improvements obtained with a laboratory conditioner by varying holding period, time of conditioning, or temperature of conditioning*

Wheat	Treatment	Flour moisture	Alveograph			Flour extraction	Dry gluten
			P	G	W		
	Holding period after treatment varied						
		Percent				*Percent*	*Percent*
	Control (no treatment)---	14	40	15.7	80	60	5
	Preheated 10' to 45° C.						
	Heated 20' at 55° C.						
Domestic, 1950 crop	Holding period: 0 hour---	14.3	45	15.9	88.4	63	7
	4 hours--	14	71	13.8	104.2	62.7	7
	6 hours--	14.1	75	13.5	102.3	63	6
	8 hours--	13.9	39	16.1	75.6	62	7
	Time of treatment varied						
	Control (no treatment)---	13.6	54	13.1	71.2	63	5
	Preheated 10' to 45° C.						
Domestic, 1950 crop	Heated 15' at 55° C.-----	13.3	30	18.1	69.2	61	6
	Heated 20' at 55° C.-----	14.2	45	17.5	101	62	6
	Heated 25' at 55° C.-----	14.7	50	17.5	109.9	63.2	6
	Temperature of conditioning varied						
	Control (no treatment)---	14	74	22	270	70	12.5
	Preheated 15' to 40° C.						
Manitoba 3 Atlantic	Heated 30' at 46° C.[1]----	14.5	75	22.1	277.3	67	12.5
	Preheated 15' to 50° C.						
	Heated 30' at 55° C.[2]----	14.2	142	21.1	495.6	68	13.3
	Control (no treatment)---	11.8	77	21.3	210	66	12
Hard Winter I	Preheated 15' to 42° C.						
	Heated 35' at 50° C.[3]----	14.4	95	21.9	299	66	12.5

[1] Held for 18 hours.
[2] Held for 17 hours.
[3] Held for 20 hours.

Source: Michelli (422, p. 122, table II).

to 0.895. Dalibor concluded that a conditioning temperature of 54° to 55° seemed to be best for improving yield.

Boulanger (92) studied the effects of conditioning on a mixture of soft German domestic wheats. Thirty tons each of wheat from the Saale, Holstein, and Lower Silesia districts were collected, characterized individually by laboratory tests, and blended. The mixture was divided into three portions for milling trials in a commercial mill and given treatments as follows:

Unconditioned.--Wheat was washed, predried with cold air, held for 24 hours, dampened, held for 4 hours, raised from 16.3- to 16.5-percent moisture content before the first break.

Conditioned at 40° C.--Wheat was washed with water at 28° C., conditioned for 150 minutes, held for 4 hours, dampened to 16.5 percent before the first break. Temperature

TABLE 44.--*Baking quality of flour from unconditioned and conditioned wheats grown in three districts of Germany*

Characteristics studied	Magdeburg			Saale			East Prussia		
	Not conditioned	Conditioned at--		Not conditioned	Conditioned at--		Not conditioned	Conditioned at--	
		45° C.	55° C.		45° C.	55° C.		45° C.	55° C.
Swelling No.-----	8.5	10.0	7.0	7	7	8	10.5	10.5	12.0
Degree of softening after 10 minutes--------	55	45	50	75	70	50	100	100	100
Loaf volume-cc.--	1,070	1,100	1,160	960	1,000	960	1,100	1,210	1,150
Height of loaf------mm.--	62	65	70	48	56	52	66	74	73
Ratio of height to width-------	.36	.38	.42	.26	.32	.30	.38	.43	.45

Source: Gehle (255, p. 122).

changes in conditioner: 34° after 7 minutes, 40° for 80 to 90 minutes, dried and cooled to 32° with hot air, cooled to 15° with cold air.

Conditioned at 58° C.--Procedure as above, but wheat was washed with water at 38°. Temperature changes in conditioner: 46° after 7 minutes, 54° after 19 minutes, 58° after 45 minutes, or somewhat sooner, continuing for 50 to 60 minutes, dried and cooled.

The effects of conditioning on the various mill streams (6 breaks, 5 early reductions, 13 middlings reductions) were evaluated by a number of laboratory tests: Farinograph, Fermentograph, Extensigraph, Berliner's gluten swelling test, gluten rest period test, ash, and baking tests.

Conclusions in regard to the break flours were that 40° C. was sufficient for improving the interior of the kernel, but that 58° was required to stabilize the flour from the outer layers. Breads from the first two of the early reductions were good whether the wheat was treated or not. Only the darker flour streams (third reduction and later) showed improvement with conditioning. At 40°, improvement was found only in the Farinograph curves. At 58°, improvement was found with all tests including the baking tests. Later middlings reductions are dark streams as indicated by their ash. They showed slight to moderate improvement with 40° conditioning and marked improvement from 58°. Although some streams even showed overconditioning, no damage appeared in the flour. Final yield and ash of the flours were as follows:

Treatment:	Yield	Ash
	Percent	*Percent*
Unconditioned	80.4	0.874
Conditioned at 40° C.	80.8	.864
Conditioned at 58° C.	82.2	.870

Moisture in each case was 15.2 percent. Three commercial bakeries agreed in their evaluation of the flours. The following characteristics were reported:

Unconditioned:	Flowing dough, less water absorption.
Conditioned at 40° C.:	Also flowing dough.
Conditioned at 58° C.:	Good shape, good oven rise and volume, insensitive during working.

The wheat mixture studied showed good response to hot conditioning. From his voluminous data on the characteristics of the various flour streams, Boulanger concluded that the outer layers of the kernel require much heat, the inner little.

Becker (61) studied the effects of hot conditioning on the gluten properties of wheat. Preliminary experiments made with a "Heilan" laboratory conditioner gave the following results:

	Moisture content	Swelling No.	Gluten
Treatment:	*Percent*		
Unconditioned	24	6	Long.
Conditioned for 1 hour at 56° C.	19.5	10	Still good.
Conditioned for 1 hour at 60° C.	16.0	12	Crumbly.
Conditioned for 1 hour at 56° and 1 hour at 60° C.	17.2	16	Crumbly.

Tests were made in a commercial mill on three 10,000-kg. lots of mixed hard and soft German domestic wheat. The control sample was merely dampened with cold water. The other two samples were washed and conditioned at 50° and 60° C., respectively (table 45). Flour, Type 790, from both unconditioned wheat and wheat conditioned at 50° yielded good bread by both laboratory and commercial methods of baking but flour from wheat conditioned at 60° produced loaves that were small and cracked. Doughs from flour of Type 2000 stayed flat and blew regardless of the method of conditioning. Fermentograph tests showed that the fermenting force was equally strong in doughs from all three methods of conditioning. Farinograph curves showed that the dough became stronger and firmer with a higher temperature of treatment. The extensigrams agreed well with the baking tests.

Hopf (328) discussed the construction and use of drying and conditioning apparatus and also the effects of heat on wheat during drying and conditioning. Data quoted (table 46) showed that usually with increased temperature or time of treatment the amount of wet gluten was constant or decreased, the swelling number was increased, and the percentage of maltose was decreased. However, at temperatures of 55° C. or lower and with grain moisture less than 20 percent, the amount of wet gluten was not decreased with added time of treatment but the swelling number was increased.

Hopf also presented conditioning schedules for hard and soft wheat based on the properties of the wheat. He stated that without an accurate knowledge of the characteristics of the wheat no proper choice of conditioning methods could be selected.

Mohs and Klemt (445) conducted experiments in a commercial mill to determine the effects of different types of conditioning on the baking quality of the flour. A 200-ton sample of average German wheat was used. It had a protein content of 13.65 percent, a wet gluten content of 25.1 percent, and a swelling number of 6.5. The moisture content was not stated, but it must have been more than 15.44 percent because flour from unconditioned wheat had that moisture. A small amount was milled, unconditioned, for a control; presumably, it was not dampened. Flours from unconditioned and conditioned wheat were tested in several laboratories and by various methods. In the first experiment, wetted wheat was conditioned at 35°, 40°, 45°, and 55° C. in a radiator conditioner. Results of the tests on the flour are given in table 47. Conditioning at 35° through 50° resulted in a decrease in the baking number of untreated flour compared with that of unconditioned wheat. The ash figure was higher than that of unconditioned wheat except when a conditioning temperature of 55° was used. From the table it appears that flour from wheat conditioned at 55° was better than that from unconditioned wheat. However, three laboratories reported that the flour showed effects of overconditioning. Another laboratory rated it better than flour from unconditioned wheat but based its opinion primarily on the higher swelling number. When the flours were chemically treated, the minimum of baking quality was found in that from wheat conditioned at 35°. The baking number increased with an increase in the conditioning temperature.

In the second experiment, washed wheat was conditioned with hot air and held for 24 hours before being milled. The maximum temperature reached by the wheat was 38° C. As in the experiment in which a radiator conditioner was used, conditioning increased the ash content of the flour and decreased the baking number. Mohs and Klemt suggested that the deterioration in baking quality might be due to an increase in yield, an increase in bran content, or an increase in proteolytic power.

Another experiment was planned to test a statement by Brabender concerning the effect of changing the amount of suction in the last conditioning blast (table 48). Untreated flours from Tests I and II, in which suction was used during conditioning, were poorer than flour from unconditioned wheat but better than flour from wheat conditioned at 50° C. with valves closed. Treated flour from Test II was noticeably better than that from unconditioned wheat and equal to that

TABLE 45.--*Comparison of unconditioned German domestic wheat with samples conditioned at 50° and 60° C.*

Experimental conditions			
Preliminary treatment	Damped	Washed	Washed
Temperature of water °C.	8	32	37
Conditioning:			
Temperature °C.	Unconditioned	50	60
Time hours	---	1.25	1.25
Moisture at feed percent	---	19.6	19.4
Moisture at delivery do	---	16.8	16.6
Over-all time hours	---	2.25	2.25
Moisture in grain to mill percent	16.8	16.6	16.7
Moisture in products do	15.7	15.5	15.8
Extraction do	77	76.5	77.4
Results of tests on grain and flour			
Grain gluten:			
Amount percent	24.0	23.5	18.0
Swelling No.	6	9.5	16.0
Extensibility	Long	Short, still good	Crumbly.
Flour gluten:			
Type 405: Amount percent	22	20	18
Swelling No.	10	15	19
Extensibility	Good, elastic	Short, elastic	Crumbly.
Type 790: Amount percent	25	25	22
Swelling No.	8.0	9.5	16
Extensibility	Long	Good, elastic	Crumbly.
Type 2000: Amount percent	27	22	20
Swelling No.	2	3-4	7
Extensibility	Long	Long	Somewhat shorter.
Additional tests, Flour Type 790			
Dough characteristics			
Ratio, width: height, 1 hour	3.48	3.24	2.32
Ratio, width: height, 2 hours	3.91	2.72	2.26
Loaf volume	980	1,040	750
Pore number	6	8	9-10

Source: Becker (61, pp. 55-56).

TABLE 46.--*Effects of time and temperature of conditioning on gluten properties of wheat*

Treatment	Treatment time	Gluten amount	Swelling No.	Maltose	Moisture after treatment
	Minutes	*Percent*		*Percent*	*Percent*
Control, untreated	---	20	3.5	0.70	13.8
Wheat damped to 17.5 percent, treated at 55° C.	20	19.0	7.5	---	17.2
	30	20.0	9.5	---	---
	40	19.0	9.0	---	---
	50	19.0	8.5	---	---
	60	20.0	11.2	.65	16.3
Wheat damped to 20.0 percent, treated at 55° C.	10	19.5	6.2	---	19.7
	20	19.5	10.5	---	---
	30	19.0	9.5	---	---
	40	19.0	10.0	---	---
	50	19.0	11.5	---	---
	60	18.0	12.5	.65	18.6
Wheat damped to 17.5 percent, treated at 60° C.	20	20.0	10.2	---	17.5
	30	20.0	12.2	---	---
	40	19.7	12.8	---	---
	50	20.0	12.2	---	---
	60	19.0	14.8	---	17.0
Wheat damped to 17.5 percent, treated at 65° C.	5	20.0	11.5	---	17.5
	10	19.5	15.6	---	---
	20	19.0	17.8	---	---
	30	17.5	20.0	---	---
	40	17.3	20.5	---	---
	50	17.0	21.5	---	---
	60	15.5	22.0	---	17.0
Wheat damped to 17.5 percent, treated at 70° C.	5	17.0	18.5	---	---
Wheat damped to 17.5 percent, treated at 75° C.	5	Could not wash out	---	---	---
Wheat damped to 18.2 percent, held for 6 hours, treated at 55° C.	10	20.0	7.0	.72	18.0
	20	20.0	7.7	---	---
	30	20.0	8.7	---	---
	40	20.0	8.2	---	---
	50	20.0	9.5	---	---
	60	20.0	12.2	.60	16.8
Wheat damped to 18.2 percent, held for 12 hours, treated at 55° C.	10	20.0	8.8	.72	18.0
	20	20.0	8.5	---	---
	30	20.0	8.0	---	---
	40	20.0	9.2	---	---
	50	20.0	10.0	---	---
	60	20.0	11.5	.65	16.8

Source: Hopf (328, table from F.P.).

TABLE 47.--*Influence of heat on gluten quality and baking quality*

Temperature, °C.	Untreated flours, Type 812				Chemically treated flours		
	Moisture, percent	Ash (d.b.)	Swelling No.	Baking No.	Ash (d.b)	Swelling No.	Baking No.
Unconditioned	15.44	0.79	6.5	93	0.83	5.0	106
35	15.27	.83	3.5	71	.82	5.5	79
40	14.95	.86	3.0	58	.87	3.5	88
45	14.84	.85	5.0	51	.85	6.0	96
50	15.04	.83	5.0	68	.81	6.0	112
55	14.82	.77	13.0	111	.76	10.0	118

Source: Mohs and Klemt (445, p. 268, table I).

of wheat conditioned with valves closed. Similar results were obtained when the experiment was repeated after about 4 weeks.

The last experiment was made, at the suggestion of Miag, to determine the effect of double conditioning on baking quality (table 49). Flour from wheat double-conditioned (tests I and II) had higher baking numbers and lower ash values than flour from wheat once-conditioned at 35° C. These differences were especially noticeable in Test I which gave flour whose baking number was nearly equal to that of unconditioned wheat.

Summarizing results, Mohs and Klemt stated that there was no increase in the baking quality of untreated flour from conditioned versus unconditioned wheat in spite of (1) increasing temperatures up to the highest permissible temperature, (2) changing the suction system according to Brabender's suggestion, and (3) double conditioning.

Gehle and Will (269), whose laboratory was one of several that had made tests on the flours from the various experiments of Mohs and Klemt (445), repeated those tests after the chemically treated flours had aged for 2 months. Data are presented in table 50. Their results showed that, in comparison with no conditioning or single conditioning, double conditioning produced a marked improvement in the baking quality of the aged, chemically treated flours.

TABLE 48.--*Influence of water extraction by suction on baking quality*

Type of test	Untreated flours, Type 812			Chemically treated flours		
	Ash (d.b.)	Swelling No.	Baking No.	Ash (d.b.)	Swelling No.	Baking No.
Unconditioned	0.79	6.5	93	0.83	5.0	106
Conditioned at 50° C., valves closed	.83	5.0	68	.81	6.0	112
Test I.--Wheat wetted, held for 12 hours, conditioned at 50°-52° C. 3rd heat blast 1/4 open, 4th heat blast 1/2 open	.84	8.5	83	.82	5.0	102
Test II.--Wheat not wetted, conditioned at 50°-52° C. 3rd heat blast 1/2 open, 4th heat blast 3/4 open	.76	---	83	.80	11.5	111

Source: Mohs and Klemt (445, p. 271, table III).

TABLE 49.--*Influence of double conditioning on baking quality*

Type of test	Untreated flours			Chemically treated flours		
	Ash (d.b.)	Swelling No.	Baking No.	Ash (d.b.)	Swelling No.	Baking No.
Unconditioned------------------------	0.79	6.5	93	0.83	5.0	106
Once conditioned at 35° C.------------	.83	3.5	71	.82	5.5	79
Test I.--Wheat conditioned at 35° C., held for 12 hours, conditioned at 35° C.-----------------------------	.74	4.0	87	.77	4.0	105
Test II.--Wheat conditioned at 35° C.,[1] conditioned at 48° C.---------------	.77	5.5	78	.77	4.5	94

[1] No holding period indicated.

Source: Mohs and Klemt (445, p. 272, table IV).

Summary

In general, the data on hot conditioning of wheat indicated that treatment of various kinds of wheat with temperatures over 46° C. brought about improvement in yield and/or baking quality of the flour (92, 145, 624, 647, 652), although in 637 the different conditioning requirements of different lots of wheat were pointed out. One article (445) reported no improvement in baking quality of hot-conditioned German wheat in comparison with that of unconditioned wheat. Laboratory studies were recommended as having direct value for commercial application (393, 422). Improvement of both overextensible (393) and poorly extensible (378, 666) gluten was reported. A little evidence for the production of biochemical changes by the high temperatures was given (142, 534, 602).

TABLE 50.--*Data from tests on aged chemically treated flours from the conditioning experiments reported by Mohs and Klemt (445)*

Treatment, temperature, °C.	Without standing		After 1 hour standing		Volume	Loaf stand	Baking No.
	Gluten amount	Q_0	Gluten amount	Q_0			
Unconditioned----------------------	25.0	9	27.5	3	1,130	28	119
Conditioned at:							
35°------------------------------	25.0	9	25.0	6	1,140	31	130
40°------------------------------	25.5	6	27.5	2	1,100	29	117
45°------------------------------	25.0	8	27.5	2	1,240	33	135
50°------------------------------	24.0	8	26.0	4	1,280	34	146
55°------------------------------	22.5	12	27.5	6	1,300	38	131
50°, valves closed---------------	22.5	9	26.5	5	1,220	37	135
50°, valves slightly open--------	21.0	10	25.0	8	960	31	74
50°, valves far open-------------	22.5	12	25.0	8	1,250	44	134
Doubled conditioned at:							
35°/35°--------------------------	25.0	10	27.5	3	1,400	46	175
35°/48°--------------------------	25.0	8	27.5	2	1,280	44	156

Source: Gehle and Will (269, p. 145).

Conditioning by Direct Application of Steam

Heat transfer from steam to wheat kernels

Heat transfer from steam to wheat kernels is much more rapid than the transfer from hot air or from radiators. Consequently, the time range for safe treatment of wheat by steam is very narrow. Cleve and Hoffmann (140) reported temperatures attained by wheat kernels following steam and hot air treatments after various periods of time. Table 94 (p. 82) illustrates the marked difference in the rate of heat exchange with steam in comparison to that with hot air. The heat transfer number of a single kernel heated by steam was more than 10 times that for a kernel treated by air at 84° C. (479:33). The difference between heating kernels singly and in a layer on a sieve was also quite marked. When heated by steam the single kernel showed a heat transfer number almost 10 times that for kernels heated in a layer (479:50). Single kernels heated by hot air showed heat transfer numbers two to three times those for wheat heated in a layer on a sieve at similar temperatures: At 77° and 76° C., respectively, the ratio was 19:7.2; at 67° and 65°, 17:6.8; and at 54° and 53.5°, 18:7.8.

Thomas, Stone, and French conditioner

Pence (490) made extensive studies on the use of steam in conditioning hard red winter wheat for milling. The conditioner[6] consisted primarily of two rotating horizontal cylinders. The upper one was equipped with steam jets for direct application of steam to the grain, while the lower cylinder provided for a controlled air blast to dry and cool the grain. A screw conveyer between the conditioning cylinder and the drying cylinder was equipped at its head with water-metering jets. This device made it possible to add water as required for milling and for evaporative cooling, and to mix the water thoroughly with the grain. Table 51 shows the temperatures and moisture percentages attained by four lots of wheat while they passed through the conditioner.

The effects of varying the holding period following conditioning with steam were compared with the effects of tempering with cool and with warm water (table 52). Attempts to mill samples held for less than 1 hour after conditioning were unsuccessful as the bran was too wet for satisfactory separation. At holding times of less than 2

TABLE 51.--*Temperature and moisture content of hard red winter wheat as it passed through the conditioner*

Position in conditioner	Trial 1	Trial 2	Trial 3	Trial 4
	Temperature, °F.			
Wheat entering machine--	76	75	75	74
Wheat after first cylinder--------------	100	99	113	132
Wheat after conveyor----	103	101	114	135
Water added in conveyor-	132	141	142	143
Wheat leaving machine---	85	85	87	88
Air for cooling---------	121	122	123	121
	Moisture in wheat, percent			
Entering machine--------	12.0	12.1	12.1	11.8
After first cylinder----	13.9	14.1	15.2	15.4
After conveyor----------	17.6	17.9	17.8	18.5
Leaving machine---------	16.5	16.7	16.4	16.3

Source: Pence (490, p. 1,547, table I).

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[6] According to a personal communication from Stephen J. Loska, Jr., this was a Thomas, Stone, and French conditioner that was commonly referred to as the Wichita Wheat (W.W.) conditioner (cf. 632, 650).

TABLE 52.--*Effect of various wheat treatments during conditioning on the analysis of the straight grade flour*

Serial No.	Temperature after 1st cylinder	Temperature of water	Temperature at tempering bins	Holding period	Moisture content of wheat	Flour				
						Yield	Moisture	Protein	Ash	Maltose
	°F.	°F.	°F.	*Hours*	%	%	%	%	%	*Mg.*
2075[1]--------	84	70	82	24	15.3	70.9	13.2	11.9	0.50	166
2004[2]--------	80	132	81	24	15.6	70.3	13.9	12.0	.47	145
2013[3]--------	103	132	83	24	14.8	71.6	13.4	11.9	.51	135
2049---------	105	132	84	24	15.7	69.1	12.9	11.7	.49	143
2010---------	104	132	80	12	15.7	70.0	14.2	11.7	.46	135
2072---------	103	132	84	8	14.8	70.4	13.1	11.8	.47	130
2009---------	102	130	82	6	15.5	70.3	13.9	11.7	.46	135
2012---------	103	132	83	4	16.7	71.0	14.3	11.7	.43	116
2028---------	103	132	82	4	14.8	71.2	13.2	11.7	.47	140
2033---------	101	131	80	2	14.0	71.5	13.0	11.6	.46	161
2042---------	102	133	83	2	15.9	71.4	12.6	11.5	.45	156
2044---------	101	131	84	2	15.6	70.2	12.8	11.5	.47	143
2047---------	100	130	85	2	15.6	68.6	12.7	11.6	.46	132
2011---------	103	131	83	1.5	16.5	69.8	13.5	11.7	.44	171
2034---------	102	133	84	1.5	14.4	71.6	12.7	11.8	.48	161
2036---------	104	130	80	1.5	16.0	70.0	13.9	11.6	.44	140
2035---------	105	132	83	1	15.2	70.0	13.5	11.4	.45	143

[1] Tempered with cool water (70° F.).

[2] Tempered with warm water (132° F.).

[3] Steam was used in the first cylinder for this sample and the succeeding samples.

Source: Pence (490, p. 1,547, table III).

hours, middlings were sharp and hard. The use of steam permitted a reduction in the holding period from 24 hours to 2 to 4 hours. Baking tests were made of the flours from the foregoing series, but they showed neither damage nor improvement as a result of conditioning; hence the data are not reproduced. The following year similar analyses and baking tests were carried out on a more extensive series of samples. Analyses of the various flour streams were also made. Again a holding time of 2 to 4 hours after steam conditioning was satisfactory and no differences in baking quality attributable to the method of conditioning could be detected.

Wichser and Shellenberger (650), in connection with studies of granulation of flour, compared the results of cold conditioning with those of warm conditioning as carried out in the Thomas, Stone, and French conditioner. Hard winter wheat was heated to 105° F. in the first cylinder, sprayed with water at 120°, cooled to 85°, held for 4 hours, and milled. Wheat was tempered in the same machine without the use of steam or hot water and milled after a holding period of 24 hours. Ash and protein of the flours obtained by both methods were 0.48 percent and 11.4 percent, respectively, on a 14-percent moisture basis. Other results were as follows:

Sample:	Mixograph mixing time	Farinograph absorption	Loaf volume	Texture score	Crumb color
	Minutes	*Percent*	*CC.*		*Cw.*
Conditioned	2.75	65	840	95	97
Tempered	2.75	65	830	95	96

Laboratory conditioners and special methods

Schäfer (in Gehle 262) compared the mellowing effect of three types of conditioning on the endosperm of wheat. An increase in break flour was indicative of greater mellowing. The variations of conditioned samples from the unconditioned are given in percentage:

Test conditions:	Total flour	Farina[1]	Ease of reduction of middlings	Break flour
Normal conditioning, Miag laboratory conditioner 43°-47° C. ..	+0.1	-0.9	+0.3	+0.6
Hot conditioning, Miag laboratory conditioner 68°-72° C.	+4.2	-2.1	+4.6	+3.0
Steam conditioning, 70°-72° C. for 15-20 sec.	+1.7	-1.7	+3.3	+1.1

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[1] Farina = 100 - (break flour + break bran).

Steam conditioning brought about more mellowing than normal conditioning but less than hot conditioning. In discussing these data Schäfer stated that mellowness can only be achieved through the use of heat.

Pelshenke and Schäfer (487) found that milling properties of Manitoba 5 wheat were not materially improved by steam conditioning for 15 seconds at an average temperature of 72° C. in comparison with normal conditioning in a Miag laboratory conditioner at 50°. Milling data were obtained with a Buhler automatic mill (table 53). Pelshenke and Schäfer considered Manitoba 5 wheat to be particularly unresponsive to conditioning treatments.

Schäfer (554) compared the effects of steam treatment with those of other methods of heat treatment. He used pure varieties of German wheats. Conditioning was done with Elcon and Miag laboratory conditioners, and milling was usually done with a Buhler mill. The steam treatment was carried on in a steam chamber. The steam temperatures given in the data signify the temperatures at the instant the steam left the steam boiler. The relation of pressure to temperature of the steam were as follows:

Atmospheres excess pressure:	Temperature, °C.
0.03	100
1.2	122
1.5	127
2.0	133
2.5	138
3.0	143
4.0	151

Data which show the effect of conditioning methods on two varieties of wheat with respect to the amount of gluten in the flour, i.e., the amount that could be washed out, are given in table 54. A reduction in the amount of gluten that could be washed out began with a steam treatment at 118° C. for 20 seconds, in contrast with 40 to 60 minutes at 70° with conventional conditioning. The ability of the gluten to be washed out ceased at 128° after 20 to 30 seconds with steam treatment in contrast

TABLE 53.--*Effects of normal and steam conditioning on milling properties of Manitoba 5 wheat*

Milling properties	Normal conditioning		Steam conditioning	
	Low extraction	High extraction	Low extraction	High extraction
Water content-----------------------percent--	15.3	15.3	15.3	15.2
Power requirement ---------------------kw.--	.20	.19	.19	.19
Flour yield------------------------percent--	55.0	81.0	57.8	81.3
Break bran----------------------------do----	18.9	10.0	18.6	8.2
Shorts--------------------------------do----	26.1	9.0	23.6	10.5
Flour ash-----------------------------do----	.65	.71	.64	.77
Bran ash------------------------------do----	5.00	5.47	5.54	5.86
Starch in bran------------------------do----	16.5	14.3	26.0	13.5

Source: Pelshenke and Schäfer (487, p. 775, table 3).

TABLE 54.--*Effect of conditioning methods on ability of gluten to be washed out*

Stage at which time and temperature were determined	Conventional conditioning (Elcon)				Steam treatment			
	Heine IV		Tassilo		Heine IV		Tassilo	
	Time	Temperature	Time	Temperature	Time	Temperature	Time	Temperature
When ability of gluten to be washed out was--	*Minutes*	°C.	*Minutes*	°C.	*Seconds*	°C.	*Seconds*	°C.
First reduced-----------	60 20	70 80	150 40	60 70	20 15	118 128	20 10	118 133
Ceased------------------	150 60	70 80	20 ---	80 ---	30 20	128 139	30 20	118 128

Source: Schäfer (554, p. 48, table 1).

with 20 to 60 minutes at 80° for conventional treatment.

Table 55, also from Schäfer (554), shows the effect of duration of steam treatment on dough properties. With the increase of time from 10 to 30 seconds and an accompanying decrease in ability of the gluten to be washed out, the swelling number and the wheat-meal time test figure increased. Increase in the time test figure was not accounted for by gelatinization of the starch; microscopic observation revealed no differences in the granules. The high wheat-meal time test figure was indicative of overtreatment of the gluten. Two treatments which differed in temperature and time, but resulted in essentially the same heating effect, yielded similar values for dough properties (table 56). The highest temperature reached by the grain determined the conditioning effect.

TABLE 55.--*Effect of time of steam treatment at 1.2 atmospheres excess pressure on dough properties*

Time, seconds	Wheat-meal time test	Swelling No., Q_0	Maltose content, percent	Amylose No.
10--------	26	12	0.97	45
20--------	53	15	.83	47
30--------	108	19	.63	60

Source: Schäfer (554, p. 48).

Schäfer also made a comparison of the effects of steam (118° C.), normal conditioning (43°-47°), and hot conditioning (68°-72°) on baking quality of flour. Table 57 shows that by every test made the quality of flour from steam-treated wheat was at least as good as that of flour from wheat treated by the other methods and that it was distinctly better in volume yield and value number. The tendency to a more tender crumb and finer pores in bread from steam-treated grain played a part in the higher value number.

Schäfer (554) found that steam treatment of grain often gave higher flour yield and required less power consumption than other treatments (tables 58 and 59). The percentage of ash in flour was sometimes less following steam treatment but also sometimes higher than with other types of conditioning (table 58). Schäfer attributed these different results to different varietal characteristics of the wheat. In all experiments yields of coarse bran were higher after steam treatment than after the other methods of conditioning. From experimental milling at flour extractions of around 65 percent and without the use of purifier or bran finisher, the coarse bran obtained

TABLE 56.--*Effect of different steam treatments on the kernel properties of Heine IV variety wheat*

Characteristics studied	Treatment: 10 seconds, 1.2 atmospheres excess pressure	Treatment: 5 seconds, 4.0 atmospheres excess pressure
Initial water content-----------------------percent--	14.4	14.3
End water content-----------------------------do----	16.8	16.7
Initial temperature-----------------------------°C.--	19.5	14.0
End temperature---------------------------------do----	59.0	60.0
Gluten content-----------------------------percent--	19.6	18.6
Swelling No., Q_0-----------------------------------	12	12
Wheat-meal time test--------------------------------	26	25
Maltose content-----------------------------percent--	0.97	0.90
Ratio, flour: semolina------------------------------	1.54	1.61

Source: Schäfer (554, p. 49, table 2).

under various conditioning methods was as follows:

Conditioning method:	*Percent*
Steam treatment	20.7
Normal conditioning	18.0
Hot conditioning	18.8
Damping	19.6

Berliner (81) studied the effect of duration of steam treatment on gluten properties. His results are given in table 60. A marked improvement in gluten properties was

TABLE 57.--*Effect of different conditioning procedures on the baking results*

Characteristics studied	Steam treatment[1]	Normal conditioning	Hot conditioning
Dough yield--------	159.0	157.7	158.9
Bread yield--------	137.0	134.9	137.0
Volume yield-------	368	350	338
Value number-------	65	49	35
Crumb somewhat harsh No.: total tests------------	[2] 7:10	5:5	2:2
Pore figure, average----------	6.75	5.92	5.65

[1] Twenty seconds at 1.1 atmospheres excess pressure.

[2] Three tests showed a nearly tender crumb.

Source: Schäfer (554, p. 49, table 3).

TABLE 58.--*Effect of different conditioning procedures on yield and ash content of flour from Heine IV variety wheat*

Treatment	Lower extraction		Higher extraction	
	Flour	Ash	Flour	Ash
	Percent	*Percent*	*Percent*	*Percent*
Steam treatment, 10 seconds--------	63.6	0.53	80.3	0.67
Steam treatment, 20 seconds--------	67.3	.49	83.3	.68
Normal conditioning-	66.1	.52	81.8	.68
Hot conditioning----	68.6	.50	81.0	.62
Damping-------------	64.2	.47	78.9	.66

Source: Schäfer (554, p. 49, table 4).

TABLE 59.--*Power consumption with different types of conditioning*

Conditioning method	*Kw.*
Steam treatment------------------	0.57
Normal conditioning-------------	.58
Hot conditioning-----------------	.58
Damping--------------------------	.59
Running empty--------------------	.42

Source: Schäfer (554, p. 50, table 6).

TABLE 60.--*Effect of short periods of steam treatment on gluten properties of wheat*

Time of treatment, seconds	Wet gluten, percent	Q_0	Q_{30}	Gluten rest period No.
Untreated-----	26.0	17.3	7.1	2.5
About 0.2-----	20.0	20.7	13.0	3.7
" .5-----	19.6	22.2	16.8	3.9
" 1.0-----	18.4	22.8	17.9	3.9
> 1.0-----	16.0	24.8	20.7	[1] 4.0

[1] Gluten very short.

Source: Berliner (81, p. 166, D).

brought about by steam treatments of one second or less. This improvement was accompanied by a decrease in the percentage of wet gluten.

Cleve (135) studied the effect of steam treatment of soft German domestic wheat on the gluten and diastatic power. Whereas 40° C. was sufficient for improvement of milling properties, modification of the gluten and enzymes required temperatures up to 65° C. Comparative data on steam-treated and untreated wheats follow:

Test:	Untreated	Treated
Swelling No. Q_0	9.5	17.7
Swelling No. Q_{30}	8.6	14.9
Extension....................	30 cm. after 78 min.	3 cm.
Extension after 30 min. dough rest...............	30 cm. after 55 min.	5-6 cm.
Maltose No.................	1.8	1.4 treated at 45° C. 1.2 treated at 64° C.

The increase in swelling number and decrease in extensibility indicated considerable improvement as a result of the steam treatment. The relative effectiveness of water extracts of the flours for degradation of starch in a standard solution was shown by color reactions with iodine. The color was yellow with the extract from untreated wheat, red with that from wheat treated at 45° C., and blue with that from wheat treated at 64°; maltose values were 1.8, 1.4, and 1.2, respectively. Treatment at 45° reduced α-amylase activity, but the higher temperature was required for nearly complete inactivation of the enzyme.

Losev (400), in an attempt to establish the biochemical changes which occur in wheat during conditioning, tempered wheat to 19-percent moisture content and heated it for 30 minutes in a steam-saturated oven at 85° C. Comparisons were made with unconditioned, cold-conditioned (18°), and warm-conditioned (27°) wheat (table 18, p. 17). Although the sample conditioned at 85° yielded the highest percentage of flour, it gave bread that had a reddish-tinged crumb whose walls were thicker and tougher than those in bread obtained from the cold-conditioned sample.

Steam-addition method

Altrogge's steam-addition method of conditioning has been rather fully described in several articles (24, 27, 137). The wheat is heated rapidly by the direct addition of steam in a worm conveyer that is installed at the head of a radiator conditioner. During the passage of the wheat through the conditioner the temperature may be maintained or increased. After the prescribed holding time at the highest temperature desired, the wheat is cooled quickly to about 40° C. Before leaving the conditioner the wheat is cooled to about 25°. The different methods used for wheats of different character are described briefly.

Method M is designed to improve the millability of hard dry wheats of high quality. Wheat is heated to 38° to 42° C. in the steam worm and enters the conditioner with a moisture content of 17 to 20 percent. The temperature in the heating sections of the conditioner is kept at 40°.

Method D is used for dry soft wheats. The wheat attains its peak temperature of 55° to 65° C. in the steam worm. In the conditioner the temperature is reduced rather quickly to 40° C. by opening exhaust valves, and this temperature is maintained for the desired time.

Method R is adapted to wheat of high initial moisture content. The temperature is approximately 40° to 45° C. at the delivery end of the worm and the peak temperature of about 60° C. is attained in the first heating blast of the radiator. The wheat is cooled to 40° during the cooling blasts and moisture is extracted in this process.

The chief advantages claimed for the steam-addition method are as follows:

Toughening of the bran.
Uniform mellowing of the endosperm.
Easier separation of bran from endosperm.

Restriction of the highest temperature reached in the kernel to its outer layers.

Schäfer (in 178, 557) attributed the easier separation of bran from endosperm to the hardening of the protein contents of the cells of the aleurone layer. This hardening, he reasoned, made it mechanically easier for the flutes of the rols to scrape the outermost endosperm cells from the bran.

Altrogge and Schäfer (28) published data which showed the effect of the steam-addition method of conditioning on some German domestic wheats. Table 61 gives data on a weak wheat and table 62, on a somewhat better wheat. The temperatures used were 57° and 69° C., respectively. Both wheats showed an increase in swelling number. In the better wheat there was a

TABLE 61.--*Analyses of wheat untreated and steam-addition treated and analyses and baking tests of the flours*

Type of investigation	Domestic wheat		Flour-type 550	
	Untreated	Treated at 57° C.	Untreated	Treated at 57° C.
Analysis:				
Moist gluten content----------percent--	20.5	20.5	26.5	26.5
Swelling number Q_0--------------------	12	13	9	11
Swelling number Q_{30}--------------------	6	8	4	6
Maltose number------------------------	---	---	2.3	2.3
Baking tests:				
Dough yield---------------------------	---	---	159.5	163.5
Volume yield--------------------------	---	---	251	280
Bread yield---------------------------	---	---	135.5	141.0

Source: Altrogge and Schäfer (28, table 5).

TABLE 62.--*Analyses of wheat untreated and steam-addition treated and analyses and baking tests of the flours*

Type of investigation	Domestic wheat		Flour-type 550	
	Untreated	Treated at 69° C.	Untreated	Treated at 69° C.
Analysis:				
Moist gluten content----------percent--	29.0	26.2	28.0	28.0
Swelling number Q_0--------------------	11	16	14	14
Swelling number Q_{30}--------------------	10	10	5	10
Wheat-meal time test------------------	33	43	-	-
Maltose number------------------------.	-	-	2.0	2.6
Extensigram, R:E----------------------	-	-	1.4	3.2
Baking tests:				
Dough yield---------------------------	-	-	158.2	158.2
Volume yield--------------------------	-	-	304	352
Bread yield---------------------------	-	-	133.6	133.2

Source: Altrogge and Schäfer (28, table 7).

drop in wet gluten as a result of treatment at a high temperature. Flour and baking tests indicated quality improvement of both wheats. Treatment of another domestic wheat at 61° brought about practically no improvement; only the extensigram ratio of resistance:extensibility (R:E) showed improvement (table 63).

TABLE 63.--*Analyses and baking tests of flour from untreated and steam-addition treated wheat*

Type of investigation	Flour-type 550	
	Untreated	Treated at 61°C.
Analysis:		
Moist gluten content-----percent--	26.5	27.0
Swelling number Q_0-----	9	9
Swelling number Q_{30}----	2	0
Maltose number---------	2.1	2.1
Extensigram, R:E-------	0.7	1.4
Baking test:		
Dough yield------------	162.0	163.0
Volume yield-----------	263	265
Bread yield------------	141.8	138.5

Source: Altrogge and Shafer (28, table 6).

Altrogge (27) gave data on conditioning and on gluten properties of untreated and steam-addition treated portions of 16 soft German wheats (table 64). His data showed that, according to average values, steam treatment reduced the amount of gluten slightly, raised the Q_0 value about two units, raised the Q_{30} value about four units, increased the wheat-meal time test figure slightly, and increased the quality number by about 10 percent. There was, however, considerable variation in gluten properties and especially in gluten amount.

Cleve (139) also reported experiments in which wheat was conditioned by the steam-addition method. In one experiment (table 65) the baking quality of samples 1 and 2 was improved by conditioning although the improvement of sample 2 was less because it had a low gluten content. The baking quality of wheat with short gluten (sample 3) was not changed. The moisture contents of the wheats were not stated. Sample 2 was conditioned at 64° C.

In another experiment Cleve (139) compared flour from unconditioned wheat with flour from wheat conditioned in a mill by the steam-addition method at 70° C. In each case flour characteristics were evaluated

TABLE 64.--*Effects of conditioning by steam-addition method on the gluten quality of soft German wheats*

Highest temperature °C.	Grain moisture			Gluten investigation											
	Before cleaning	At outlet of--		Amount of gluten		Q_0		Q_{30}		Gluten degradation		Wheat-meal time test		Quality No.	
		Washer	Conditioner	0[1]	Conditioned	0	Conditioned	0	Conditioned	0	Conditioned	0	Conditioned	0	Conditioned
60---------	16.9	---	15.8	23.0	23.4	23	24	17	18	74	75	39	49	4825	5435
54---------	19.7	---	16.3	19.8	20.2	21	23	18	22	86	96	26	33	3895	4455
57---------	15.3	---	15.8	23.4	23.6	18	19	11	14	58	78	39	46	4335	4790
50---------	15.4	17.3	15.5	25.0	25.2	15	17	9	11	60	65	39	42	4075	4430
54---------	16.1	---	16.1	24.2	24.6	16	20	5	11	31	55	34	35	3905	4365
59---------	15.9	17.7	16.1	23.6	23.4	18	22	7	10	39	46	31	38	3940	4685
59---------	16.2	18.1	16.9	23.4	23.6	20	20	11	14	55	70	38	46	4485	4890
72---------	16.3	---	16.5	24.6	23.0	18	21	11	17	61	81	55	64	5165	5675
70---------	16.0	---	15.8	21.9	21.0	16	20	15	18	94	90	45	64	4398	5525
61---------	16.3	---	16.7	22.4	20.4	20	24	16	23	80	96	41	59	4610	5360
66---------	15.7	17.7	16.2	20.4	20.6	19	21	15	18	79	86	50	58	4910	5515
64---------	15.8	17.8	16.0	21.0	21.6	20	20	8	12	40	60	40	54	4525	5240
61---------	15.9	18.2	16.5	21.6	21.0	22	22	17	21	77	96	52	52	5340	5325
62---------	16.0	---	16.2	21.0	19.6	22	24	14	17	64	71	37	37	4575	4740
61---------	15.2	17.5	15.9	24.6	23.6	21	23	16	20	76	87	67	61	5715	5890
62---------	16.2	---	15.7	17.6	17.2	18	20	13	16	72	80	39	41	4190	4480
Range															
50	15.2	---	15.5	17.6	17.2	15	17	5	10	39	55	26	33	3895	4365
72[2]	19.7	---	16.9	25.0	25.2	23	24	18	23	94	96	67	64	5715	5890
Average 60.7------	16.2	17.8	16.1	22.7	22.3	19.2	21.2	12.7	16.4	65	77	42	49	4555	5050

[1] 0 = not conditioned.

[2] Printed as 70 in journal.

Source: Altrogee (27, table 2).

TABLE 65.--*Effect of conditioning by the steam-addition method on the baking quality of three weak wheats*

Characteristics studied	Sample 1		Sample 2		Sample 3	
	Unconditioned	Conditioned	Unconditioned	Conditioned	Unconditioned	Conditioned
Gluten in flour------percent--	21.0	21.4	16.4	15.8	18.7	18.1
Extensigram, R:E--------------	2.8	3.3	1.7	2.0	4.2	4.5
Volume yield------------------	362	408	367	392	380	385
Main fermentation, minutes----	46	59	50	58	53	52

Source: Cleve (139, p. 184, table 2).

without and with the addition of "Multafort," an ascorbic acid preparation. A stored, dried, domestic German wheat, characteristic of wheats being milled commercially, was used. Results are given in table 66. Conditioning did not affect the amount of gluten, and the addition of Multafort affected it only very slightly. Conditioning shortened the gluten, although different tests indicated different degrees of shortening. Extensigram data showed only a slight decrease in extensibility but a definite increase in resistance of the gluten following conditioning. These effects were heightened markedly by the addition of Multafort to the conditioned flour. According to the dough softening extensigrams, use of conditioning alone and of Multafort alone shortened the gluten to about the same extent. When they were used together, an additive effect was apparent. Judged by baking tests, conditioning, use of Multafort, or 3 weeks' aging of the flour brought about improvement of the flour. Combinations of these treatments seldom showed additive effects and in some cases brought about no improvement over the control.

"Stabilisor"

The "Stabilisor," described by Lockwood (395) and Sugden (610), is a conditioning apparatus that has twin worm conveyers in which the wheat is heated by steam jets to any selected temperature between 120° and 150° F. in about 50 seconds. The grain absorbs about 2.5-percent moisture from the condensed steam. The wheat passes through the steam worms in about 1 minute and is discharged into a washer where it is immediately cooled. There it picks up an additional 2 percent of water. Originally dry wheat may be ready to mill after 12 hours' standing time but moist wheat may need to be dried. Some of the advantages claimed for Stabilisor-treated wheat are that it mills well with low consumption of power and gives flour of good quality because the bran is easily separated from the endosperm. For strengthening of weak gluten the steamed wheat is held for 2.5 to 5 minutes in a special hot bin before it goes to the washer.

Lockwood and Sugden presented extensigrams showing the effect of various Stabilisor treatments with and without chemical additives on Manitoba 3 wheat. Sugden also gave extensigrams, farinograms, and extensimeter curves of soft European wheats. In general, the curves showed that the overextensible gluten of weak wheats was made more stable and less extensible by the Stabilisor process.

Forster conditioner

The Forster conditioner (41, 199, 401) is the short-time conditioner most used in the United States and Canada. It consists of two stationary horizontal cylinders with conveying paddles, cooling tower(s), and accessory controls and equipment. Dry steam at not over 5 p.s.i. is injected into the first cylinder raising the temperature of the grain to 115° to 120° F. Each kernel acts as a condenser and absorbs the moisture condensed. Condensation amounts to about 0.9 percent moisture per 20° rise in tem-

TABLE 66.--*Characteristics of flour from unconditioned and conditioned wheat. Evaluations made with and without the addition of ascorbic acid ("Multafort")*

Characteristics studied	Control sample				Conditioned, max. temp. 70° C.			
	Baked at once		Stored for 3 weeks		Baked at once		Stored for 3 weeks	
	No Multafort	12 g. Multafort	No Multafort	12 g. Multafort	No Multafort	12 g. Multafort	No Multafort	12 g. Multafort
Analysis:								
Ash (d.b.)-----percent--	0.71	0.71			0.69	0.69		
Gluten-----------do-----	24.8	24.3			24.7	24.5		
Swelling No. 0----------	19	19			19	20		
Swelling No. 30---------	13	16			17	16		
Extension 0-------------	1.6	1.7			2.1	1.4		
Extension 30------------	5.0	2.9			4.3	2.5		
Extensigram:								
Resistance--------------	280	290			300	510		
Extensibility-----------	135	135			127	97		
R:E---------------------	2.1	2.2			2.4	5.3		
Area--------------------	54.6	45.5			49.1	61.8		
Dough softening extensigram:								
10 minutes--------------	420	500			530	560		
45 minutes--------------	240	270			300	390		
90 minutes--------------	180	200			230	300		
After 90 minutes standing-------------------								
10 minutes--------------	330	450			480	600		
45 minutes--------------	180	290			260	440		
90 minutes--------------	120	170			200	250		
Baking test:								
Dough yield-------------	164.5	164.5	165.5	164.5	163.5	163.5	165.0	165.0
Main fermentation, minutes---------------	45	45	42	46	50	55	52	58
Rise in oven------------	12	16	20	19	14	11	14	13
Loaf volume-------------	1,060	1,160	1,020	1,040	1,080	1,060	1,020	1,060
Height:width--------mm--	66:178	74:173	73:165	74:164	70:172	74:174	71:169	75:168
Height:width---percent--	37	43	44	45	41	43	42	45
Elasticity--------------	Satisfactory	Quite good.	Good	Good	Satisfactory	Satisfactory	Satisfactory	Quite good.
Pore walls--------------	Tender	Quite woolly	Woolly	Woolly	Quite tender	Quite tender	Quite harsh	Quite woolly.
Uniformity--------------	Not uniform	Not uniform	Rather ununiform	Rather ununiform	Not uniform	Not uniform	Not uniform	Not uniform
Porosity----------------	6-7	7	7	7-8	6	6	6	6
Crust-------------------	Crisp	Crisp	Crisp	Crisp	Crisp	Crisp	Crisp	Crisp.
Browning----------------	Uniformly medium		Medium		Uniformly medium		Medium.	
Evaluation:								
Volume yield------------	436	478	423	428	442	434	420	437
Baking No.--------------	100	122	100	108	97	94	91	95
Bread yield-------------	144.0	144.0	145.0	144.0	143.0	143.0	144.2	144.2
Value No.---------------	105	142	140	148	97	94	86	115

Source: Cleve (139, p. 185, table 3).

perature for the dry steam used. In the second cylinder sufficient tempering water is added to raise the moisture to the level desired at the first break and to allow for the loss of moisture during evaporative cooling of the grain. After passing through the cooling tower, grain (generally at 90°-95°) goes to the holding bin for a rest period of 1 to 4 hours, then to a final cleaner, a second cooling tower to reduce grain temperature to 80° to 85° (if necessary), and on to the mill. Advantages claimed for this method of conditioning (41) include accurate control of the conditioning process, a short time-factor permitting adjustments for changes in mill atmosphere, production of warm tough bran and good middlings which purify, grind, and bolt well, and low power costs (not over 0.2 cents per bushel).

Summary

With few exceptions the data on steam conditioning showed that flour from steam-conditioned German domestic wheat was of better quality than flour from unconditioned wheat (27, 28, 81, 135, 139). Comparison of steam conditioning with normal and hot conditioning (554) indicated that steam conditioning required less power, often resulted in a higher yield of flour and of coarse bran, and gave flour of as high or higher quality than that obtained after other methods of conditioning. One investigator (490) found that steam conditioning improved the millability of hard red winter wheat but did not improve the baking quality of the flour; another investigator (400) reported that flour from steam-treated wheat made poorer bread than that from cold-conditioned wheat.

VACUUM CONDITIONING

Vacuum Drying as a Step in Conditioning

Benefits claimed

Dienst (161, 163, 165) was one of the chief proponents of the vacuum method of conditioning. He pointed out (161) that the vacuum apparatus, as developed by him, was not a conditioner but a highly efficient drier giving the greatest drying effect with the most uniformity at the lowest grain temperature and with the least consumption of heat. Its use as a conditioner involves the following principles: Naturally moist grain, or grain that has been dampened to at least 2 to 3 percent more moisture than required for milling and allowed to swell, is exposed in a vertical-flow continuous process under vacuum to heating and vaporization of moisture. Cool incoming grain is heated rapidly by the condensation of steam vaporized from the grain in the lower drying compartments and then completes its swelling. After vacuum drying, the grain is cooled at atmospheric pressure. Drying under vacuum results in a rapid uniform boiling away of the water within each kernel at a temperature not injurious to the grain (33° C. at 95 percent vacuum). The grain is perfectly mellowed without shrinkage. Benefits claimed for the process (163, 165) include drying of grain with varying moisture content to a uniform moisture, production of higher yields of brighter flour (rye showed 3 to 4 percent greater yield with power savings of 8 to 10 percent), and safe and efficient operation.

A recent modification suggested by Dienst (165) involves a closely controlled steaming of the grain at 1.5 atmospheres pressure just prior to the vacuum treatment at 0.05 atmosphere pressure. This modification reduces the time required for initial swelling of the wheat and improves loosening of the bran.

Experimental results

Kuprits and others (382) studied the effect of vacuum drying and conditioning at three temperatures on the gluten quality of two varieties of wheat. The varieties used and their respective characteristics were as follows:

	Moisture	Ash	Hardness	Germination	Wet gluten	Weight
Wheat:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*G./l.*
Melanopus 69...	11.3	1.87	82	90	28	793
Melturum 321..	11.0	1.74	35	87	28	773

The wheats were tempered to a uniformly high moisture level, about 27 percent, before they were dried; samples 3 kg. in size were treated. Only the results of tests of the flours from samples of Melanopus 69 were tabulated; they are given in table 67.

TABLE 67.--*Influence of vacuum treatment on gluten characteristics of Melanopus 69 wheat*

Test	Flour from untreated grain	Flour from grain conditioned at--					
		40° C.		50° C.		60° C.	
		and dried for--					
		3 hours	5 hours	3 hours	5 hours	3 hours	5 hours
Wet gluten--------------percent--	28	30	31	29	29	22	21
Dry gluten-------------------do--	11	11	11	11	11	10	9
Extensibility---------------mm.--	16	15	13	12.5	12	10	10
Absorption--------------percent--	155	175	182	163	163	120	133

Source: Kuprits and others (382, p. 202).

Drying at 40° and 50° C. improved baking qualities of the flour, but drying at 60° resulted in too low extensibility of the gluten and lower absorption and gave a coarse, short dough. When Melturum 321 variety was dried for 5 hours at 50° from a moisture content of 27 percent down to 10 percent, baking tests indicated that no changes had occurred in gluten quality.

The milling advantages claimed by Kuprits and others (382) for conditioning by the vacuum method were better and more rapid separation of bran from endosperm, improved gluten qualities, lower ash content of flour, and a reduction of 17 to 39 percent in cost of power.

Cleve (128) compared the baking quality of flour from unconditioned, radiator-conditioned, and vacuum-conditioned wheat. The wheat was damped to 21 to 22 percent moisture and held for 16 hours. A portion was conditioned normally in a laboratory radiator conditioner at 58° C.; another portion was conditioned by the vacuum method. No details of the latter procedure were given. Tests of gluten properties and loaf characteristics showed that normal and vacuum conditioning produced similar results. The gluten was shortened and the loaf volume was often increased by both methods of conditioning. Data for the three wheats tested are given in table 68.

Two papers from the Institute for Milling at Berlin, by Mohs (444) and by Schmidt (573), reported improvement in the baking quality of wheat that was either purposely or accidentally wetted to a high moisture content and then dried in a vacuum conditioner. The experiments reported by Mohs were on a wheat mixture that had a moisture of 17.4-17.5 percent, a hectoliter weight of 76 to 77 kg., and 18 percent wet gluten. Samples 1-8 (100 sacks of wheat/sample) were treated in a mill at Niesky as follows:

Sample
No.

1. Control, cleaned dry and not conditioned.
2-8. Preliminary treatment. All washed and damped to 20-21 percent moisture, held for 6 hours.
2-5. Conditioned in vacuum conditioner at 40°, 50°, 60°, and 70° C., respectively, for 40 minutes. Final moisture content 17.2 percent.

TABLE 68.--*Effects of radiator and vacuum conditioning on baking quality of flour*

Characteristics studied	Mill mix, North Germany			Strube's Red Schlanstedter			Mill mix, Central Germany		
	Un-cond.	Normal cond.	Vac. cond.	Un-cond.	Normal cond.	Vac. cond.	Un-cond.	Normal cond.	Vac. cond.
Wheat-meal time test-------------	54	70	90	44	77	66	44	44	46
Wet gluten---------	20	20	20	22	22.5	22.5	20	20	20
Swelling No.-------	8	10	9	8	8	8	9	8	9
Extensibility-mm.--	[1] 90	[1] 15	[1] 16	[2] 125	[2] 64	[2] 40	[1] 40	[1] 20	[1] 15
Loaf volume---cc.--	1,300	1,400	1,370	1,190	1,230	1,240	1,130	1,130	1,150
Height: width of loaf----------	34	47	42	35	40	39	37	41	42
Porosity-----------	6	7	7	7	8	8	8	8	8
Baking No.---------	126	162	151	138	146	148	123	123	131
Flour + bromate + malt									
Volume cc.-----	1,550	1,610	1,650	1,420	1,470	1,460	1,430	1,550	1,550
Height: Width of loaf------	39	45	44	41	42	39	40	44	44
Porosity-------	6	6	5	7	6-7	-7	7	7	6-7
Baking No.-----	164	177	162	168	166	171	166	187	178

[1] After 120 minutes.
[2] After 60 minutes.

Source: Cleve (128, table 1).

Sample No.

6-8. Double conditioned.

6. Conditioned in vacuum conditioner at 45° to 47° C. to 14.2-percent moisture content, cooled for 20 minutes, held for 4 hours, washed and wetted to 17-percent moisture content, held for 6 hours, conditioned at 40°-45° C. to 17.2 percent moisture.

7. Treated as sample 6, except that temperature during first conditioning was 52° to 55° C.

8. Treated as sample 6 with two exceptions: (1) Temperature during first conditioning was 50° to 54° C.; (2) after drying to 14.2 percent moisture, the wheat was held warm for approximately 3 hours before wetting to 17-percent moisture content.

Milling was regulated to attain a yield of 81.6 to 81.8 percent and the following throughs with sieve No. 20: First break, about 20 percent; second break, 30 to 35 percent; special break, 70 to 75 percent. Table 69 shows the variations obtained. Flours were tested after 4 weeks' storage. The results of the tests, except those for acidity and maltose which showed only slight and somewhat inconsistent variation, are reproduced in table 70. The greatest improvement in baking quality was obtained by drying from 21- to 17.2- percent moisture content with single conditioning at 60°

TABLE 69.--*Effect of different methods of vacuum conditioning on the millability of a wheat mixture that was damped to 20-21 percent moisture and held for 6 hours*

Sample No.[1]	First break	Second break	Special break	Endosperm	Bran	Shorts
	Percent	*Percent*	*Percent*			
2----------------	20.0	32.5	70.0	Normal	Normal	Normal.
3----------------	23.0	42.0	62.0	Mellower	Woolly	Brighter.
4----------------	20.0	44.0	62.5	Like 3	Like 3	Like 3.
5----------------	18.5	40.0	70.0	Like 3	Like 3	Normal.
6----------------	20.0	42.5	67.5	Very mellow	Larger	Normal.
7----------------	22.0	43.0	74.0	Very mellow	Normal	Normal.
8----------------	25.0	40.0	50.0	Normal	Normal	Normal.

[1] Samples 2-5, single-conditioned; samples 6-8, double-conditioned.

Source: Mohs (444, p. 93).

TABLE 70.--*Gluten characteristics and average baking number of flour from German domestic wheat after single and double vacuum conditioning at various temperatures*

Sample No.[1]	Water content	Wet gluten		Swelling No.		Extensibility (Kosmin-Kranz)				Average baking No.
		At once	After 1 hour	At once	After 1 hour	At once		After 1 hour		
						Length	Time	Length	Time	
	Percent	*Percent*	*Percent*			*Cm.*	*Minutes*	*Cm.*	*Minutes*	
1------	16.28	17.70	17.30	11	7	16.0	70	32.5	45	22
2------	15.91	18.10	18.50	11	6	To bottom	43	15.0	40	32
3------	15.55	18.20	18.70	12	7	24.5	50	To bottom	40	19
4------	15.76	18.10	17.07	19	19	Not torn	120	18.5	34	44
5------	15.81	Could not be washed out		---	---	---	---	---	---	0
6------	15.12	18.60	19.60	12	7	To bottom	58	To bottom	35	9
7------	15.26	19.90	18.00	10	7	5.0	55	32.0	45	27
8------	15.96	20.80	19.80	9	8	29.5	50	To bottom	30	44

[1] Sample 1, unconditioned; samples 2-5, single-conditioned; samples 6-8, double-conditioned.

Source: Mohs (444, p. 93).

C. (sample 4). Both swelling number and extensibility were increased and the average baking number rose from 22 to 44. These results are also referred to by Mohs (in 7) and by Dienst (154).

Schmidt's paper (573) gave the results of tests for milling and baking quality of Karachi wheat that had been soaked to 23- and to 42-percent moisture content when a loaded barge sank in the Havel River near Deetz, Germany. The soaked wheat was dried to 15- and to 18-percent moisture content, respectively, in a vacuum conditioner at 50° C. Some dry wheat (11-percent moisture) had been salvaged and that served as a control. All three samples gave 4 percent screenings when cleaned. They were damped, held for 16 hours, and 30 kg. of each were milled at 17.5-percent moisture content on an experimental mill to flours of uniform ash content (Type 812). Both samples of soaked wheat, but especially that soaked to 23 percent, milled more easily than the control wheat. Compared with the control, wheat soaked to 23 percent moisture yielded 3 percent more flour. Some characteristics of the flours from the three samples are given in table 71. Wheat soaked to 23 percent gave lower acidity and maltose values than did the control, but that soaked to 42 percent gave higher acidity and lower maltose values. These results indicated that soaking to different percentages of moisture content had different inhibiting effects on enzymatic activity. This conclusion was substantiated by the following results of tests for diastatic power and water-soluble dry substance:

	Diastatic power (after Lintner)	Water-soluble dry substance
Sample:		
Original wheat	50	9.42
Soaked to 23 percent moisture	50	8.63
Soaked to 42 percent moisture	33	9.19

The data also show that in comparison with the control the gluten of the soaked wheat showed a slight increase in swelling number, a decrease in firmness and, for that soaked to 23 percent, a slight increase in extensibility. These changes were desirable because the gluten of the Karachi wheat was too short.

Evaluation of flour quality by means of the Farinograph gave the results presented in table 72. From the longer kneading time required by the flour of soaked wheats, Schmidt inferred greater stability of the gluten. The stability figure, 45, for wheat soaked to 23-percent moisture content was higher than that of the control. The strong

TABLE 71.--*Comparison of flours from dry and soaked Karachi wheat*

Characteristics studied	Original wheat	Wheat soaked to 23%	Wheat soaked to 42%
Water content-------------------percent--	13.0	13.1	12.1
Ash (d.b.)-------------------------do----	.87	.85	.86
Acidity, filtrate-----------------------	1.87	1.75	2.25
Acidity, suspension---------------------	3.75	3.62	4.00
Maltose-------------------------percent--	3.17	2.79	2.85
Wet gluten------------------------do----	16.7	17.5	16.0
Gluten swelling No.---------------------	19	22	21
Gluten extensibility (Kosmin-Kranz):			
Length---------------------------cm.--	1	1	.5
Time-------------------------minutes--	120	120	120
Gluten stability (Schopper):			
Firmness--------------------------g.--	297	258	258
Extensibility--------------------mm.--	43.4	46.6	42.5
Stability-----------------------sec.--	17.5	16.2	14.6

Source: Schmidt (573, p. 154, table 1).

decline of the rest period curves suggested to Schmidt that the dough was affected by enzyme activity. The flour from wheat soaked to 23 percent moisture showed the least enzymatic effect.

Results of evaluation by Extensigraph curves are given in table 73. Extensigrams showed that the short, firm gluten of the control had been softened during the wetting and drying of the wheat.

From baking tests it was apparent that flour from the wheat soaked to 23 percent moisture gave loaves somewhat superior in volume, pore formation, and baking number (table 74).

Outer-layer process

Fritsch (217) discussed in detail the structure and properties of the various layers of the bran and the effects of mois-

TABLE 72.--*Data from Farinograph curves of flours from dry and soaked Karachi wheat*

Characteristics studied	Normal curve			Curve after a rest period of 1 hour		
	Original	Soaked to 23 percent	Soaked to 42 percent	Original	Soaked to 23 percent	Soaked to 42 percent
Water absorption--	63.1	60.4	60.2	---	---	---
Development time--	2	2.25	2.25	---	---	---
Stability---------	40	45	35	20	20	15
Drop before kneading-------------	---	---	---	140	110	130
Drop after kneading-------------	120	100	120	230	210	245

Source: Schmidt (573, p. 157, table 3).

TABLE 73.--*Data from Extensigraph curves of flours from dry and soaked Karachi wheat*

Rest period of dough, minutes	Original wheat		Wheat soaked to 23 percent		Wheat soaked to 42 percent	
	Max. height	Max. length	Max. height	Max. length	Max. height	Max. length
	Curves of water-dough					
45-------------------------------------	430	10.0	465	9.7	460	8.0
90-------------------------------------	615	9.5	505	12.0	500	9.8
135------------------------------------	640	11.5	495	13.8	500	12.2
180------------------------------------	650	6.0	605	13.9	540	12.6
Average--------------------------------	591	10.9	518	12.4	500	10.7
	Curves of yeast-salt-dough					
45-------------------------------------	620	7.2	540	7.7	590	6.5
90-------------------------------------	710	7.3	570	7.7	590	6.4
135------------------------------------	710	6.0	660	8.0	475	5.7
180------------------------------------	650	6.0	560	7.2	495	6.1
Average--------------------------------	663	6.6	583	7.7	538	6.2

Source: Schmidt (573, p. 158, table 4).

ture and heat in aiding their separation from the endosperm. He pointed out (210, 219) that an unhomogeneous mellowing of the kernel such as is produced by the outer-layer conditioning process may be preferable to a homogeneous mellowing. In a description of the Miag-Wille-Fritsch outer-layer process, Fritsch and Cleve (223) stated that the grain is evacuated at its natural moisture content and then immersed in water or a special tempering solution where the normal air pressure is restored. The grain then passes to the washer and whizzer, and to the drier if necessary. It is claimed that this process hastens the penetration of moisture into the capillaries of the kernels and aids in separation of the bran from the endosperm. The conditioning effect is heightened by the use of lactic acid or other chemicals in the tempering water to modify the outer layers.

Cleve (134) compared the effects of the outer-layer process (using lactic acid solution) with that of damping alone on the quality of flour obtained from German domestic wheat. Exact details of his experiments were not reported. The results of his tests are given in tables 75 and 76.

TABLE 74.--*Baking tests of flours from dry and soaked Karachi wheat*

Sample	Dough yield	Fermenting time of a piece of dough	Bread yield	Baking loss	Volume yield	Pore No.	Baking No.
		Minutes		*Percent*			
Original wheat	179	48	152	15.7	420	7-8	87
Soaked to 23 percent	176	46	149	15.3	430	8	110
Soaked to 42 percent	174	46	147	15.3	406	8	94

Source: Schmidt (573, p. 159, table 5).

TABLE 75.--*Tests on three types of finished flours from German domestic wheat normally dampened and from that treated by the outer-layer process*

Characteristics studied	Normally dampened			Outer-layer process		
	550	812	1050	550	812	1050
Gluten:						
Wet gluten--percent	30.5	32.0	34.0	30.0	31.5	34.0
Swelling No., Q_0	8.5	5.5	4	10.5	5	4
Swelling No., Q_{30}	1.5	0	0	1.5	0.5	0.5
Extensibility$_0$[1]	60	35	25	60	50	25
Extensibility$_{30}$[1]	30	15	20	30	20	10
Extensigram:						
Extensibility--mm.	203	229	218	197	224	215
Resistance to extension	130	120	140	190	160	170
Resistance: extensibility	0.63	0.52	0.6	1.0	0.7	0.8
Area--sq. cm.	37.3	32.5	36.8	69.3	48.6	43.5
Baking test:						
Dough yield--percent	162	162	163.5	163.5	166	167.5
Main fermentation--min.	30	30	36	40	40	35
Loaf height:width--percent	36	35	21	39	32	29
Pore No.	8	7-8	5-6	8	7-8	6-7
Volume--ml.	374	390	308	408	354	314
Baking No.	74	86	6	104	51	12
Value	89	96	11	129	71	19

[1] Minutes to 30 cm.

Source: Cleve (134, p. 542, table 1).

TABLE 76.--*Average of tests on straight run flours from German domestic wheat normally dampened and from that treated by the outer-layer process*

Characteristics studied	Normally dampened	Outer-layer process	Percentage difference
Extraction of flour Type 812, percent	78	81	+4
Gluten:			
Wet gluten, percent	34.3	32.3	-6
Swelling No., Q_0	6	7.9	+32
Swelling No., Q_{30}	2.2	2.6	+18
Extensibility$_0$[1]	37	56	+51
Extensibility$_{30}$[1]	17	30	+77
Extensigram:			
Extensibility, mm.	228	206	-10
Resistance to extension	133	189	+42
Resistance: extensibility	0.53	0.77	+46
Area, sq. cm.	65	104	+59
Baking test:			
Dough yield	171	170.6	±0
Main fermentation, minutes	41.4	41.2	±0
Loaf height: width, percent	26.2	30.1	+15
Pore No.	7	7.5	
Volume, ml	400	450	+13
Baking No.	80	115	+42
Value	93	133	+43

[1] Minutes to 30 cm.

Source: Cleve (134, p. 542, table 2).

Cleve called attention to the improvements shown by extensigrams and to the increase in loaf volume brought about by the outer-layer process. The ash curve for flour from outer-layer processed wheat indicated lower ash at all extractions than in flour from damped wheat.

With respect to some trials in a commercial mill, Cleve (134) stated that extraction of flour was over 1 percent higher after outer-layer treatment than after normal conditioning.

Summary

Vacuum conditioning is essentially vacuum drying of naturally moist grain, or of grain which has previously been moistened with water or steam to a moisture content higher than that required for milling (128, 161, 163, 165, 382, 444, 573). Advantages claimed for this method of conditioning are uniform moisture content of the grain, higher yields of brighter flour, and safe and efficient operation (163, 165). Baking quality of the flour may be improved (128, 382, 444, 573), although it appears sometimes to be unaffected (128, 382, 444).

A variation of vacuum conditioning is the outer-layer process (223) in which grain at natural moisture content is subjected to vacuum and subsequently treated with water, and sometimes chemicals, with a concurrent return to normal air pressure. The outer-layer process is claimed to give improved milling (134, 219, 223) and, in some cases, to increase extraction and to improve flour quality (134).

SPECIAL METHODS OF HEATING WHEAT DURING CONDITIONING

Additional methods of heating wheat during conditioning include heating by ultrasonic waves, high frequency current, electric condenser, and infrared rays. These methods permit rapid heating with close automatic control; consequently, they are valuable for laboratory studies of specific conditioning effects. Only infrared heating has been used commercially.

Ultrasonic Waves

Anders (34) studied the effect on the gluten of heating soft wheat with ultrasonic waves. Time and power used in treatment and the medium for transmission of sound waves were varied. Results of germination and gluten quality tests are given in tables 77 and 78. The most important improvement in the swelling number was achieved by a treatment time of 6 minutes. For practical purposes, immersion in an aqueous conducting medium for periods longer than 2 to 3 minutes is unsatisfactory because of too great absorption of water. Some loosening of bran and mellowing of endosperm were noted, but other effects on milling were not investigated.

High Frequency Current

Scott (586) discussed briefly the possibilities of heating grain in an electrical

TABLE 77.--*Treatment of soft wheat with ultrasonic waves. Effects of time and power used in treatment on gluten quality and germination of kernels (Sound wave carrier - distilled water)*

Test No.	Treatment		Moisture content at the break	Gluten quality		Gluten rest period No.	Germination
	Time	Power		Q_0	Q_{30}		
	Minutes	*Kv.*	*Percent*				*Percent*
1------------------------	Untreated		18.9	3.5	0	4	96
2------------------------	1	2	19.7	3	0	4	94
3------------------------	1	3	19.7	2	0	4	93
4------------------------	1	4	19.7	4.5	1	4	96
5------------------------	1	5	18.0	3	1	4	97
6------------------------	2	2	18.4	3	1	4	96
7------------------------	2	3	20.1	5	1	4	96
8------------------------	2	4	19.5	6	1	4	93
9------------------------	2	5	17.5	4.5	1	4	93

Source: Anders (34, p. 381, table 1).

TABLE 78.--*Treatment of soft wheat with ultrasonic waves. Influence of water and lactic acid as sound wave carriers and of time of treatment on gluten quality*

Test No.	Sound wave carrier	Treatment		Moisture content at the break	Gluten quality		Gluten rest period No.	Temperature, measured at the edge of the sound cone
		Time	Power		Q_0	Q_{30}		
		Minutes	*Kv.*	*Percent*				° *C.*
1-----------	Untreated-----	---	---	25.2	0	0	4	---
2-----------	Tap water-----	3	5	25.8	1	1	4	48
3-----------	Tap water-----	6	5	21.0	6	4	4	58
4-----------	0.1% lactic acid--------	3	5	26.9	0	0	4	48
5-----------	1.0% lactic acid--------	3	5	26.2	1	0	4	48

Source: Anders (34, p. 381, table 2).

field by the use of waves of ultra high frequency alternating current. Since such waves raise the temperature of the grain by activation of the electrons within the substances composing the kernels, heating is uniform. High temperatures can be attained in a matter of seconds throughout the grain mass and throughout all parts of the individual kernels. Scott stated that, according to reports, the method had been used successfully and at a practical cost for sterilization of packaged foods by drying.

Condenser System

Annen (38) conducted experiments to determine the physical-chemical changes brought about in wheat by application of heat and moisture. He used a laboratory electric conditioner in which the grain was placed between two metal plates which were part of an alternating current condenser system. He considered that this method of heating was especially suited to laboratory conditioning because temperatures of 40° to 60° C. could be attained uniformly throughout the grain mass in a few minutes with convenient and accurate automatic controls.

Annen provided graphic data showing the linear increase in the swelling number of the gluten of German domestic wheat with increased temperature of treatment. With time of treatment held constant at 1 hour the swelling number rose from a value of 2 at 40° C. to 11 at 60°. In addition to the increase in swelling number with higher temperatures, a decrease in extensibility was found. The optimum hardness and extensibility of the gluten was reached at 55°. A decrease in maltose from 0.67 to 0.63 percent in the example given was not considered important, because with either percentage the diastatic power would need fortifying.

Berliner (71) discussed the experimental conditioning of wheat in the "Elcon" (electric condenser) conditioner and expressed the opinions: Wheat can be brought to a temperature of 60° to 70° C. in a few minutes and held at the desired temperature for as long or as short a time as required and cooled quickly. Gluten hardening is dependent on the highest temperature attained by the wheat and on the moisture content of the wheat. The germ and the outer layers of the kernel are the areas requiring treatment at high temperatures to decrease enzyme activity and to harden the gluten. Such effects can be achieved by a short intensive heating in the Elcon conditioner. Mellowing of the endosperm can then be brought about by treatment at lower temperatures over a longer period of time.

Berliner (81), in the course of studies on the effects of heat on gluten content and gluten strength, studied the response of wheat to treatment in an Elcon conditioner and to exposure to infrared heating. Evaluations of gluten properties of the untreated and the treated wheat are shown in table 79.

TABLE 79. --*Effects of two methods of hot conditioning on gluten properties*

Method	Time	Temperature	Wet gluten	Q_0	Q_{30}	Gluten rest period No.	Diastatic power
		° C.	*Percent*				
Elcon (Electric condenser)-----	---	Control	29.6	9.0	0.5	2.0	1.52
	10 minutes	60	29.5	13.4	2.3	2.5	1.31
		70	25.0	17.5	9.4	[1] 3.7	1.10
		90	Gluten decomposed				.88
Infrared---------	---	Control	23.0	3.9	1.3	1.0	
	30 seconds	50	22.0	5.8	1.8	1.2	
	30 seconds	65.	20.4	9.5	2.2	3.0	
	40 seconds	65	(21.4)	(7.9)	(1.2)	3.0	
	40 seconds	70	18.4	12.1	1.7	3.0	

[1] Somewhat short.

Source: Berliner (81, p. 166, tables C, E).

As the temperature of the treatment was increased, the amount of wet gluten was decreased and the stability of the gluten was increased. When a temperature of 90° C. was reached in the Elcon conditioner, the gluten was decomposed; at a temperature of 70°, the gluten became somewhat short.

Infrared

The theory of infrared heating for drying and conditioning of grain has been discussed by Hoffmann (310), Linder (389), and Kipper and Rumpf (362). More fundamental considerations of the theory of radiation may be found in texts on physics and engineering.

Berliner's studies (81) of the effect of infrared heating on gluten quality have already been mentioned (p. 67). Anders (34) studied improvement of gluten properties by use of infrared heating with three bright rays of 250 watts. Wheat that had been insect-damaged and wheat that had been sprouted artificially in the laboratory were treated and milled (tables 80 and 81). Improvements in gluten quality resulted from the treatments. Weak, extensible gluten was strengthened. Irradiation of a single-kernel layer of wheat, under the experimental conditions used, often resulted in overtreatment as indicated by excessive shortening of the gluten. No baking tests were made, although Anders pointed out the need of such tests for a full evaluation of the treatment.

Hoffmann (310) discussed the practical application of infrared irradiation to drying and conditioning of grain. He stated that good drying results had been obtained by heating freshly washed rye to 35° to 40° C.

TABLE 80.--*Effect of infrared treatment of insect-damaged wheat on gluten quality*

Temperature increase during irradiation, °C.	Time of irradiation	Supporting plate	Depth of layer	Wet gluten in meal	Swelling number		Wheat-meal time test	Gluten rest period No.	Gluten properties
					Q_0	Q_{30}			
	Minutes			*Percent*					
Not irradiated---	---	---	---	23.3	1	0	38	2	Extensible, slightly elastic.
15-100----------	4	Glass	1.3 cm.	21.1	4	0	34	2	Extensible, slightly elastic.
15-110----------	8	---do---	1.3 cm.	18.8	6	1	29	2	Extensible, elastic.
15-100----------	4	---do---	1 kernel	21.0	13	2	43	3	Short, elastic (somewhat friable).
15-100----------	4	Aluminum	1.3 cm.	22.3	4	0	32	2	Extensible, elastic.
15-110----------	5	---do---	1.3 cm.	22.3	4	0	28	2	Elastic.
15-100----------	3	---do---	1 kernel	21.0	11	2	44	2	Very short, elastic (somewhat friable).
15-120----------	4	---do---	1 kernel	Gluten could not be washed out					

Source: Anders (34, p. 382, table 3).

TABLE 81.--*Effect of infrared treatment of sprouted wheat on gluten quality*

Wheat	Temperature increase during irradiation	Time of irradiation	Supporting plate	Depth of layer	Wet gluten content	Swelling number		Wheat-meal time test	Gluten rest period No.	Gluten properties
						Q_0	Q_{30}			
	°C.	*Minutes*			*Percent*					
Not washed, not irradiated------	---	---	---	---	16.3	7	3	40	4	Elastic.
Washed, not irradiated--------	---	---	---	---	15.7	0	0	18	1-2	Very extensible, not elastic.
Washed, irradiated	15-100	3.5	Glass	1 kernel	16.6	3	1	24	1-2	Extensible, somewhat elastic.
	15-110	4		1 kernel	13.4	11	7	28	1-2	Very short, somewhat friable.
		4		1.3 cm.	16.4	2	0	29	1-2	Extensible, not elastic.

Source: Anders (34, p. 383, table 4).

in 15 to 17 seconds and removing the moisture with a current of air. He pointed out that infrared drying was not economical unless electric power was very cheap and that danger of fire in a mill was greater with an infrared drier than with a warm-air drier.

In a later article Hoffmann (313) compared the cost in Germany in 1954 of drying grain by hot air after radiator preheating with drying it by cold air after infrared heating. He based the number of kilocalories required to evaporate 1 kg. of water from the grain on the figures of Linder and others (390) for infrared drying and on figures which he stated were drawn from Lockwood, for the normal hot-air drying with radiator preheating. His calculations follow:

1. Hot-air drying with radiator preheating:

Assumed expense for coke..........	6.50 DM/50 kg. coke or 0.13 DM/1 kg. coke.
Heating value of coke.................	8,000 kcal./kg.
Efficiency of boiler.....................	65 percent.
Efficient heat (heat value) from 1 kg. coke............................	5,200 kcal.
Cost of 5,200 kcal......................	0.13 DM.
Cost of 1,000 kcal......................	0.025 DM.
Expense per kg. water vaporized..	0.025 to 0.03 DM.

2. Cold-air drying with infrared heating:

1,000 kcal. = 1.16 kw.-hr.	
At 0.12 DM/kw.-hr. 1,000 kcal. cost....................................	0.14 DM.
Expenses for vaporization of:	
1 kg. natural moisture................	0.40 DM.
1 kg. surface moisture	0.195 DM.

This comparison gives further evidence that economical drying by infrared heating would be dependent on very cheap electric power.

At the fourth Jugenheim conference, Kipper (360) presented data on the drying of washed wheat and rye by infrared irradiation and subsequent aeration. The data on wheat were as follows:

Sampling time:	Moisture, percent	Wet gluten, percent	Q_0	Q_{30}	Gluten rest period No.	Diastatic power	Temperature
							°C.
Unwashed......	15.1	17.4	22.1	12.5	3.7	2.87	7
After washer.	18.1	---	---	---	---	---	7
After infra-red hood......	17.8	---	---	---	---	---	30
Before milling	16.2	17.4	21.0	13.3	3.8	2.60	10

At the temperature attained only a little change in gluten properties was evident. About 800 calories were required to evaporate 1 kg. of water, which at prevailing power rates would cost about 0.07 German marks.

In another talk in the same year Kipper (361) stated that with an infrared drier of 800 kg./hr. capacity and 18 kw./hr. power consumption, the most economical drying temperature was between 40° and 45° C. Drying effects of 1.5 to 3.0 percent were attained. The process was less suited for drying naturally moist grain than for drying washed grain because intermittent drying was necessary for the former kind.

Kipper and Rumpf (362) discussed the theory of infrared heating and its use in industry and milling, especially with respect to drying of washed grain and naturally moist grain. Their discussion was based on extensive commercial experience in drying wheat and rye by infrared irradiation followed by aeration. Heating to 45° C. was attained in 15 to 20 seconds. Aeration resulted in moisture losses of 1.5 to 2.0 percent. The authors stated that economical drying of grain of naturally high moisture content is possible only by intermittent heating followed by aeration. The effects of infrared irradiation on gluten properties of French soft wheat were investigated at two temperatures with varied treatments (table 82).

Linder and others (390), at the fifth Jugenheim conference, reported data on the drying of washed wheat and naturally moist wheat with infrared irradiation (table 83). The influence of such treatment on the gluten quality of the wheat is shown in table 84.

Rumpf (544) discussed, in the light of his own experience, the treatment of grain with radiant heat. He had used radiant heat for the following purposes:

1. To dry naturally moist grain to a state suitable for milling.
2. To dry grain after washing.
3. To treat grain for improvement of milling and baking quality.
4. To dry washer waste, germ, and flakes.

TABLE 83.--*Infrared treatment of wheat*

Sample	Moisture before irradiation	Moisture after irradiation and aeration	Treatment temperature	Energy used (water evaporated)
	Percent	*Percent*	°C.	*Kw./kg.*
Wheat from washer--	19.2	16.7	43.5	1.4
Wheat damp at harvest----	19.2	17.0	41.0	3.3

Source: Linder and others (390, p. 156, tables 1, 2).

TABLE 82.--*Effects on dough properties of French soft wheat of infrared irradiation with and without subsequent standing periods*

Treatment	Wet gluten	Q_0	Q_{30}	Gluten rest period No.	Diastatic power	Moisture
	Percent					*Percent*
Untreated----------------------	22.6	2.6	0.2	1.8	1.45	16.4
Irradiated to 68° C., cooled---	19.2	10.7	1.8	2.0	1.26	15.6
Irradiated to 74° C., held for 20 minutes-------------------	18.4	13.8	3.2	3.0	1.34	15.5
Irradiated to 68° C., held for 105 minutes------------------	17.4	19.3	9.8	3.9	1.31	15.5
Irradiated to 68° C., held for 150 minutes------------------	16.4	22.4	13.4	3.8	1.15	15.4

Source: Kipper and Rumpf (362, p. 408).

TABLE 84.--*Influence of irradiation on gluten quality of wheat*

Treatment	Moist gluten, percent	Q_0	Q_{30}	Gluten rest period No.	Diastatic power
Drying after harvest:					
Not irradiated------------------------	20.8	6.1	0.8	1.0	1.31
Irradiated, 41° C.--------------------	20.4	6.6	.9	1.0	1.31
Drying after washer:					
Not irradiated------------------------	20.0	20.2	13.6	[1] 3.9	2.12
Irradiated, 40.5° C.------------------	20.0	21.0	15.0	[1] 3.9	1.88
Conditioning:					
Not irradiated------------------------	22.0	6.4	1.4	1.0	1.82
Irradiated, 60° C.--------------------	20.0	12.4	4.1	2.6	1.72

[1] Somewhat short.

Source: Linder and others (390, p. 156, table 3).

Rumpf stated that in Germany dark radiators (500°-700° C.) were preferred to light radiators (1,000°-2,000° C.). He described drying of naturally moist grain with cool air in aerated silos with a subsequent short supplementary treatment to remove moisture accumulated at the surface during the sweating of the grain. He had dried washed grain, also, quite successfully with infrared heating. For this purpose inadequate heaters do more harm than good, he reported, because they merely heat the surface moisture and so bring about a more rapid penetration of water into the kernel rather than a vaporization of the water. He stated that the minimum installation of heating elements, reckoned in kilowatts, should equal the mill output in tons/24 hours and that the heat could be utilized best by passing the grain, with kernels close together, in a thin layer under the rays. Rumpf claimed that infrared irradiation of washed grain always led to the production of flour with favorable ash and extraction figures and good baking quality. The following data illustrate the improvement in gluten and flour properties of a soft wheat mixture (cf. 544, p. 222, table 3):

Characteristics studied:	Wheat Unwashed, untreated	 Washed, treated with infrared, 80° C.
Wet gluten..........percent..	18.8	18.4
Gluten structure, Q_0	6.4	16.8
Gluten degradation, Q_{30}	1.6	3.7
Gluten rest period No.......	1.0	3.8
Diastatic power (maltose, percent)......................	1.37	1.08
Moisture............percent..	16.6	15.7

Rumpf and Kipper (545) presented data on the effect of heat treatment with infrared rays on sprout-damaged German domestic wheat. The weak, overextensible gluten was considerably shortened and diastatic power was reduced by heating to 75° C. as shown in the following tabulation (cf. 545, p. 1, table 3):

Characteristics studied:	Wheat Untreated	 Treated
Wet gluten.......................percent..	21.8	17.0
Gluten structure Q_0	11.0	17.9
Gluten degradation Q_{30}	2.6	11.3
Gluten rest period No.....................	2.5	[1] 3.8
Diastatic power (maltose, percent)...	2.50	2.11

---

[1] Somewhat short.

Rumpf (543) spoke at the sixth Jugenheim conference in 1955 on the subject of infrared drying of grain. He stated that the power required for conditioning 100 kg. of grain by infrared rays is about 2.5 to 3 kilowatts. Twenty kilowatts will heat 10 sacks to 40° to 50° C., but only 6 sacks to 70° to 80° C. He also said that there were 15 commercial installations employing infrared irradiation in West Germany and that the mills considered that the cost was covered by increased yield and quality of flour.

Summary

Some attention has been given to the possible use of ultrasonic waves (34), high frequency current (586), and an electric condenser system (38, 71, 81) in the conditioning of wheat. These methods of heating have, however, apparently been confined to experimental studies. From the articles reviewed it appears that infrared radiation is used to some extent in Germany to dry grain for milling and that the cost is compensated for by the increased yield and quality of flour obtained (543). Washed grain can be dried more easily and more economically than naturally moist grain (361, 362). However, naturally moist grain can be intermittently dried with cool air in aerated silos and given short supplementary treatments with radiant heat (362, 544).

Experimental results have indicated that weak, overextensible gluten (in wheat damaged by insects or by sprouting or in undamaged wheat) can be strengthened and shortened through radiation; the increase in Q_o is sometimes accompanied by excessive shortening of the gluten. Data comparing the effects on gluten of heating by radiation and by conventional hot conditioning methods have not been found.

PART II.--DATA IN THE LITERATURE ON SUBJECTS RELATED TO CONDITIONING OF WHEAT

HYGROSCOPICITY OF WHEAT

The capacity of grain to exchange moisture with the surrounding air is a well-known phenomenon. Phases of this interchange have been subjects for a number of studies significant to conditioning wheat for milling.

Mixtures of Wet and Dry Grains

Mixing wet and dry wheat for the purpose of drying or preserving the wet wheat and adding moisture to the dry wheat is a practical method that has been used for many years. Examination of the practice by the British National Institute for Agricultural Arts (in 13) has indicated certain facts: Complete equalization was not found, although approximate equilibration occurred in 2 to 4 days. Even after 16 days, differences of 0.06 to 1.75 percent between wet and dry samples remained. Relative humidity of the air between the kernels assumed a value intermediate between the respective humidities of the interseed air of the wet and dry grains within 3 minutes after being mixed. Air movement did not accelerate moisture exchange, the rate of exchange being limited by the diffusion of moisture from the wet kernels into the interseed air and from the air into the dry kernels. Within the range of 19° to 32° C., a higher temperature did not accelerate the rate of transfer of moisture within a 6-hour period.

Pfeuffer (500) studied the effect of temperature on the rate of moisture exchange in mixtures of equal parts of wet and dry grains. Two trials were made with wheats differing in moisture content. Table 85 shows that the rate of exchange was quite slow at the low temperatures used. The effect of three temperatures on the rate of moisture exchange was studied in a mixture of equal parts of German domestic and Argentine rye of 23- and 13-percent moisture content, respectively. Results are given in table 86. Higher temperatures had a marked effect on the rate of moisture exchange. Samples at 52° C. were nearly at equilibrium in 2.5 hours being only 0.4 percent apart in moisture content, while at 34° samples were still 1.0 percent apart after 24 hours and at 17° samples still differed by 3.4 percent after 48 hours.

Fairbrother (187) studied the interchange of moisture between paired samples of a number of different types of wheat. His results (table 87) indicated that the major interchange of moisture took place in the first 40 hours. Equalization was not attained; the final differences was about 2 percent. The wet wheat appeared to reach its equilibrium level somewhat sooner than did the dry wheat. Little difference was found between sealed samples and those held in an open flask.

Weber (648) examined the effects of mixing a wet Dickkopf wheat and a dry Australian wheat in a 2 to 1 proportion, with the following results:

Wheat:	Moisture content-- Initial	 After 10 Days	Change
	Percent	*Percent*	*Percent*
Dickkopf	18.0	15.8	-2.2
Australian	10.5	14.9	+4.4
Mixture	15.5	15.5	None

It has been suggested (11) that moisture variations of 0.5 percent in the mill mix

TABLE 85.--*Moisture interchange at 10° C. between damp and dry wheats in a 50-50 mixture*

Standing time, hour(s)	Moisture content in--	
	Domestic wheat	Foreign wheat
	Percent	*Percent*
0	16.5	13.8
1	16.5	13.8
2	16.5	13.8
18	16.4	13.9
48	16.3	14.0
0	20.6	13.8
1	20.5	13.9
2	20.4	14.0
3	20.3	14.1
4	20.2	14.2
8	19.9	14.5
12	19.5	14.9
24	19.2	15.2
48	18.6	15.8

Source: Pfeuffer (500, p. 665, tables for figs. 2, 3).

TABLE 86.--*Moisture interchange between dry and damp rye at 3 temperatures*

Temperature and standing time, hour(s)	Moisture content of--	
	German rye	Argentine rye
At 17° C.:	*Percent*	*Percent*
0	23	13
1	21.6	14.4
2	21.2	14.8
3	20.9	15.1
4	20.7	15.3
6	20.5	15.5
24	20.0	16.0
36	19.8	16.2
48	19.7	16.3
At 34° C.:		
1	21.3	14.7
2	20.7	15.3
3	20.2	15.8
4	19.8	16.2
6	19.5	16.5
24	18.7	17.7
At 52° C.:		
1	19.6	16.4
1.5	19	17
2	18.5	17.5
2.5	18.2	17.8

Source: Pfeuffer (500, pp. 665-666, table for fig. 4)

may affect the milling in a closely regulated mill. The practice of mixing wet and dry wheats to attain a desired average value requires much time and may still leave moisture differences greater than 0.5 percent. With samples color-coded to permit positive separation of kernels after being mixed, equal portions of two wheats mixed and stored in a closed box showed the following changes in moisture:

Standing time, hour(s):	Moisture content in-- German domestic wheat	Foreign wheat
	Percent	*Percent*
0	18.8	12.4
1	18.0	13.2
2	17.6	13.6
3	17.2	14.0
4	16.9	14.3
5	16.7	14.5
9	16.3	14.9
18	16.0	15.2
336	15.8	15.4

Robinson (527) reported similar data on mixing Turkey and Marquis varieties of wheat differing in moisture content. Samples did not reach equal moisture content but remained 0.8 percent apart even after 63 days:

Standing time, hour(s):	Moisture content of-- Turkey var.	Marquis var.
	Percent	*Percent*
0	15.45	9.55
9	14.20	10.80
23	13.80	11.20
50	13.45	11.55
72	13.30	11.70
96	13.25	11.75
144	13.10	11.90
192	13.00	12.00
216	12.95	12.05
336	12.90	12.10
432	12.95	12.05
576	12.90	12.10
720	12.90	12.10
1,008	12.90	12.10
1,512	12.90	12.10

TABLE 87. --*Interchange of moisture in wheat*

Container and wheat	Moisture content after--							
	0 hours	18 hours	40 hours	64 hours	84 hours	102 hours		
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Closed flask:								
German-----------------	17.28	15.95	15.90	15.23	15.42	15.39	---	---
N. Spring Pacific------	12.08	13.53	13.99	13.94	13.67	13.80	---	---
	0 hours	18 hours	40 hours	64 hours	84 hours	112 hours	162 hours	186 hours
Closed flask:								
German-----------------	17.33	15.64	14.85	14.60	15.07	14.75	14.88	14.79
Australian-------------	10.07	11.38	11.87	12.27	12.70	12.84	12.38	12.71
Open flask:								
German-----------------	17.33	15.59	14.76	14.71	---	---	---	14.80
Australian-------------	10.07	11.48	12.15	12.30	---	---	---	12.56
	0 hours	18 hours	42 hours	66 hours	90 hours	138 hours	162 hours	186 hours
Closed flask:								
English----------------	18.53	16.59	15.69	15.52	15.58	15.27	15.44	15.45
Australian-------------	9.76	12.37	13.02	13.48	13.52	13.51	13.77	13.65
Open flask:								
English----------------	18.53	16.67	16.00	15.34	---	---	---	15.44
Australian-------------	9.76	12.27	12.99	13.27	---	---	---	13.72
	0 hours	16 hours	40 hours	64 hours	88 hours	136 hours	160 hours	
Closed flask:								
English----------------	18.30	17.02	17.08	16.68	16.84	16.94	16.86	
Plate------------------	13.62	14.62	14.81	14.61	14.95	15.00	14.94	
	0 hours	18 hours	42 hours	66 hours	90 hours	162 hours	186 hours	216 hours
[Flask not stated]								
English----------------	18.41	17.43	17.15	16.85	17.14	16.78	16.50	16.80
Karachi----------------	12.68	13.55	13.83	14.31	14.32	14.42	14.15	14.40

Source: Fairbrother (187, p. 393, Table III).

Repetition of the experiment with moisture levels of the two wheats reversed gave similar results.

Fisher and Jones (193) reported results obtained from mixing two wheats differing in moisture content (table 88). Rates of absorption of these wheats were also shown graphically. In the English-Durum mixture (75:25 percent), the moisture taken up in the first 2 hours was almost equal to that absorbed in the next 22 hours. At 2 days, interchange of moisture was nearly complete and changes were insignificant after 3 days. When hard durum and English wheat of equal moisture content were exposed to the same humidity and temperature, the durum wheat absorbed moisture 20 percent faster than did the soft English wheat. Fisher and Jones noted that the smaller kernel size of the durum wheat provided a

TABLE 88.--*Moisture exchange between wet and dry wheats*

Time of testing	Moisture		
	English (50%)	Karachi (50%)	Difference
	Percent	*Percent*	*Percent*
Before mixing	20.65	10.10	10.55
After mixing[1]	16.98	14.54	2.44
Before mixing	21.99	12.62	9.37
After mixing[2]	17.92	16.80	1.12
		(Sample wetted)	
Before mixing	11.36	26.56	15.20
After mixing[2]	19.42	20.00	.58
	English (75%)	Durum (25%)	Difference
Before mixing	21.39	9.74	11.65
After mixing[3]	18.67	17.53	1.14
	English (50%)	Durum (50%)	Difference
After mixing[4]	16.51	14.66	1.85

[1] Mean of 17 moisture determinations during 6 to 47 days of standing.
[2] Mean of 7 moisture determinations during 5 to 25 days of standing.
[3] Mean of 4 moisture determinations after 4, 6, 26, and 29 days of standing.
[4] Mean values from 4, 6, and 29 days, of mixture of English and durum wheats.

Source: Fisher and Jones (193, pp. 574-579, tables I-IV), and Swanson (621, p. 12a, table I).

larger absorptive area which may have accounted for the faster rate of absorption by the durum wheat under these conditions. They concluded that the well-known difficulty of getting sufficient moisture into dry wheats, such as durum and Karachi, was due solely to their extreme dryness, not to their hardness.

Ulrich (636) discussed the equalization of moisture between lots of German domestic wheat stored in a bin of 500- to 700-ton capacity. At the time of storage the wheats ranged in moisture content from 16 to 18.5 percent. The grain was not turned or aerated. Seventeen samples taken after 3 months' winter storage showed a range in moisture content from 16.3 to 18.0 percent. Samplings from other bins, taken after shorter periods of storage, yielded somewhat similar results:

Storage time, weeks	Moisture range	Difference
	Percent	*Percent*
3	17.2-17.9	0.7
2	16.7-17.6	.9
4	16.4-17.0	.6
4	16.7-17.3	.6
3	16.6-17.9	1.3
6	16.4-17.3	.9

Ulrich concluded that moisture equalization is approached in bulked grain only after a long time and that differences of 0.4 to 0.9 percent still remain.

Owen (470) studied the uptake of water by wheat exposed to a series of high humidities for periods up to 7 days. He controlled humidities with six solutions of sodium chloride varying in molarity from 0 to 0.55 M. He plotted uptake of water in percentage of moisture (d.b.) vs. water potential for living and dead seeds of Squarehead Masters wheat. Curves were similar until germination effects resulted in a much larger uptake of water in the living seeds.

Oxley (471) studied the variations in water content among individual kernels of small samples of wheat stored one month or longer in sealed containers. Single kernel moisture determinations made of 40 kernels from each sample showed standard deviations ranging from 0.13 to 0.41 percent. The range of water content was temporarily increased upon exposure of the wheat to very dry or very damp atmospheres, thus indicating a difference in the rate of response of the kernels to such changes. Studies of the moisture content of kernels of single heads of wheat at harvest showed wide variations. Analyses of 40 kernels of a single "dead ripe" head showed a range in moisture content from 14.0 to 17.1 percent and a standard deviation of 0.74. Samples exposed to drying conditions showed skew distributions, since the presence of a number of kernels which responded rapidly to the drying conditions was not accompanied by a similar number which responded slowly.

Oxley (472) studied the mechanics of the movement of heat and water in stored grain. Heat is transferred by conduction from kernel to kernel and also by conduction and convection through intergranular air, radiation, and evaporation and condensation of water. Water is transferred solely in a vertical direction when it is applied in liquid phase to a grain mass. The water runs down until the water retained by the kernels over which it has passed equals the amount of water applied. Water in vapor phase moves by diffusion from within each kernel throughout the grain mass and is carried by convection currents following temperature gradients.

Haltmeier (293) discussed the possibilities of using the relative humidity of interseed air as an indication of the moisture content of the grain. At high humidities large deviations appeared which precluded the use of the method for estimating the moisture content with a reasonable degree of accuracy. At low humidities the deviations among different samples were reduced to such a degree that the use of an accurate hygrometer and a chart of moisture content vs. relative humidity resulted in accuracy sufficient for practical use in correcting ash figures in flour to a dry basis. Curves were presented for Manitoba and German domestic wheat. They showed that the Manitoba retained less moisture at a given humidity than did the domestic wheat, although differences disappeared below 15 percent relative humidity. One experiment which showed this difference was performed as follows: A flat container separated into two horizontal compartments by a 1-mm. screen had Manitoba wheat in the bottom and domestic wheat in the top for trial 1. In trial 2 the positions of the wheats were reversed. After 72 hours the humidity of the interseed air was nearly identical, being 64 percent for the Manitoba and 65 percent for the domestic wheat. Manitoba wheat had a moisture content of 12.76 and 12.65 percent for trial 1 and trial 2, respectively, and domestic wheat had 13.96 and 14.08 percent, respectively.

Beuschlein and Barkey (87) studied the hygroscopic capacity of wheat in equilibrium with air of fixed humidities and reported the percentages of moisture (d.b.) of 10 samples of wheat at equilibrium with air of a number of different relative humidities at three temperatures. Results of average values are given in table 89. A marked decrease in hygroscopicity with increasing temperature is apparent.

Dillman (168) reported extensive studies of the hygroscopic capacities of flax, corn, and wheat exposed to controlled humidities at various temperatures. Data on wheat show the extent and rate of moisture absorption at holding times up to 1 week (table 90).

Dillman also studied the rate of absorption of hygroscopic moisture by wheat of 9.7-percent water content as affected by temperature. At 10° C. all seeds exposed to a saturated atmosphere absorbed moisture slowly and were not yet at equilibrium in 10 days. At 30° grain absorbed moisture approximately twice as rapidly at first and was still absorbing after 10 days at about the same rate as at 10°. At 40° initial absorption was slightly more rapid than at 30°, but after 2 days the rate fell to less than that for 30°. After 10 days wheat at 40° appeared to be essentially at

TABLE 89.--*Relative humidity of interseed air and moisture content of wheat at various temperatures*

At 25° C.		At 50° C.		At 75° C.	
Relative humidity	Moisture content	Relative humidity	Moisture content	Relative humidity	Moisture content
Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
12.0	6.2	14.4	6.2	---	---
22.2	9.7	---	---	24.0	6.7
25.8	9.3	30.0	8.1	---	---
37.1	10.6	---	---	39.9	8.3
43.6	12.6	49.7	11.1	---	---
51.7	14.3	---	---	58.0	11.0
65.8	16.9	70.6	14.8	---	---
78.2	18.8	80.2	18.0	---	---

Source: Beuschlein and Barkey (87, p. 373, table IV).

TABLE 90.--*Moisture content of wheat exposed to atmospheres of different humidities at about 25° C. The initial moisture content was 8 percent*

R.H., percent	Exposed for--							
	2 hours	4 hours	8 hours	14 hours	24 hours	2 days	3 days	7 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
100--------------------	8.9	9.4	10.5	11.7	14.6	17.9	20.6	25.5
90---------------------	8.8	9.3	10.1	11.3	13.7	16.8	18.8	21.7
75---------------------	8.3	8.5	8.9	9.2	10.3	11.2	13.1	15.1
45---------------------	8.1	8.2	8.3	8.5	8.8	9.3	9.6	10.0

Source: Dillman (168, p. 57, table 2).

equilibrium in contrast to wheats at 30° and 10°, which were still absorbing. Dillman noted that the rate of absorption did not depend alone on relative humidity, but showed a marked dependency on temperature. The absolute humidity and vapor pressure vary directly with temperature. Dillman concluded that vapor pressure had a marked effect on the rate of absorption of hygroscopic moisture.

Hubbard and others (332) determined the moisture content of a number of varieties of wheat at equilibrium with air of a series of relative humidities over the range 0 to 97 percent. Both desorption and adsorption curves were determined and found to be sigmoid. Moisture content of wheat at equilibrium with air of 75- to 76-percent relative humidity was determined at three temperatures (from tables II and III and fig. 1):

	Moisture content at--		
	25° C.	30° C.	35° C.
	Percent	*Percent*	*Percent*
Wheat desorbing moisture......	15.5	15.0	14.2
Wheat adsorbing moisture......	14.7	14.4	13.6
Difference or hysteresis......	.8	.6	.6

Data extended over the full range of humidity showed no influence of temperature on the extent of hysteresis. The maximum hysteresis effect was found between 12 and 44 percent relative humidity and amounted to 1.6 percent.

Gane (231) studied the water content of three types of wheat in their approach to equilibrium with air of a wide range of fixed humidities. Whole kernels and grain ground to approximately 20 mesh in a coffee mill attained at 10° C. essentially equal moisture levels at approximate equilibrium. Days were required for whole kernels to reach equilibrium, whereas hours sufficed for the ground grain. Over the range 0° to 25° higher temperatures resulted in lower equilibrium hygroscopic moisture contents. Equilibration proceeded more rapidly at higher temperatures.

Gay (232) reported hygroscopic equilibria of wheat over the range of 20- to 80-percent relative humidity at temperatures of 50° to 100° F. His graph showed the sharp increase in hygroscopic capacity at and above 70-percent humidity.

Babbitt (52) studied the hygroscopic capacity of Garnet variety wheat at 24.5° C. over the full range of relative humidities from 0 to 100 percent while grain was both desorbing and adsorbing moisture. The desorption curve was sigmoid in agreement with reports of other workers, but the adsorption curve was distinctly convex to the humidity axis.

In a later work Babbitt (54) reported additional data indicating a possible sigmoid adsorption curve, but still concluded that the adsorption curve for wheat was convex to the relative humidity axis. He calculated diffusion coefficients and rates of approach to equilibrium. Whole kernels and kernels with the pericarp removed were found to approach equilibrium at practically the same rate. Apparently little resistance to moisture movement in vapor phase was offered by the pericarp.

Becker and Sallans (62) found that the standard solution of the nonstationary-state diffusion equation for the diffusion out of spheres is applicable to the drying of wheat kernels. In the important drying range of 12 to 30 percent the diffusion coefficient is independent of the moisture content. They also reported (65) that the properties of the coefficient for the diffusion of moisture out of wheat are directly related to the desorption isotherm. A 3-dimensional mechanism applies at moisture levels above 10 to 12 percent (d.b.), while below this critical level a 2-dimensional mechanism best explains the diffusion coefficient.

Summary

From the literature it is evident that periods up to several days in length are required for approximate equilibration of moisture between lots of wheat that differ in moisture when they are mixed together (11, 13, 187, 193, 500, 527). However, equal moisture levels are usually not attained even after periods of many days (11, 13, 187, 193, 527, 636, 648). Equilibration is more rapid at high temperatures than at low ones (500) and at higher moisture levels than at lower levels (187, 193). In large bins in which the wheat is not mixed, turned, or aerated, considerable moisture gradients may still remain after extended storage (636).

Hygroscopicity of wheat kernels varies with temperature and relative humidity of the surrounding air (87, 168, 232, 293, 332, 471, 472), and absorption-desorption isotherms have been determined (52, 54, 62, 65, 168, 231, 332). Moisture content of individual kernels in a single head of wheat at harvest time has been reported to vary considerably (471).

ABSORPTION AND TRANSMISSION OF HEAT BY WHEAT

Thermal Properties of Wheat

Specific heat

Many workers have studied the thermal properties of wheat in relation to heating and cooling during drying and conditioning. Wheat is not a single element but is made up of a number of materials differing in density and in specific heat. The varying content of water (sp. heat = 1.00) and of air (sp. heat = 0.24), and the manner of determination of the specific heat, result in differences in the specific heat value found for different wheat samples.

Schäfer (560) reviewed methods for determining and calculating the specific heat of grain and grain products. He also reviewed some of the data of Disney (169), Pfalzner (497), and Moote (449) on the effects of moisture content of the grain on the values obtained. Schäfer (560, p. 269) determined the specific heat (c) of wheat at three moisture levels over five temperature ranges:

Specific heat of wheat in kcal./kg./°C.

Moisture content, percent:	c_{20}^{40}	c_{20}^{50}	c_{20}^{55}	c_{20}^{65}	c_{20}^{70}	Average
13.0	0.398	0.423	0.433	0.457	0.470	0.436
15.7	.438	.455	.464	.485	.494	.467
19.9	.485	.506	.516	.531	.536	.515
Average	.440	.461	.471	.491	.500	

An increase in specific heat with an increase in moisture content and also with an increase in temperature of determination is apparent. Plots of specific heat vs. moisture and of specific heat vs. temperature showed a linear relation in both cases. A graph that showed the relation between specific heat and temperature for the bran, only, of Northern spring and Carstens V wheat indicated that the relation was not linear. A sharp break occurred at 55° C. Nearly linear relations were shown graphically between temperature and specific heat for flour and for wheat starch.

The type of wheat was shown to affect the specific heat; Carstens V had a lower specific heat than did Northern spring. Several empirical formulas for the calculation of specific heat (c) were discussed. One which takes into account both moisture content of grain (F) in percent and temperature of the determination (t) in °C. is:

$$c\frac{t}{20} = 0.18 + 0.002t + 0.011\,F \text{ kcal./kg./}^{\circ}\text{C.}$$

Babbitt (53) studied the thermal properties of No. 1 seed grade Marquis variety at 9.2-percent moisture content (d.b.) in bulk storage. He determined the thermal conductivity (k), the thermal diffusivity (K), and calculated the specific heat (c) according to the formula:

$$c = \frac{k}{K\varrho}$$

Where

ϱ = density (i.e., bulk density = 0.85 g./cc.),

(k) = 0.00036 cal. per cm.^{2}/sec./°C./cm.,

(K) = 0.00115 cm.^{2}/sec., and

(c) = 0.37 cal./g./°C.

Thermodynamic calculations

Becker and Sallans (63) applied the thermodynamic equation[7] to desorption isotherms of wheat at 25° and 50° C. Calculated differential net heats of desorption indicated that the initial heat was from 7 to 10 kcal. per mole of water desorbed.

Becker and Sallans (64) studied the relationships between time, temperature, and moisture content in the heat treatment of wheat and flour and the loaf volume obtained by the bromate formula. Denaturation of the gluten was found to be a first-order reaction. The rate constant, derived by expressing loaf volume for the treated sample as a fraction of the control, showed a temperature dependency which followed the Arrhenius equation. The calculated energy of activation was found to have an average and virtually constant value of 64.6 kcal. per mol. over the range of 8- to 20-percent moisture content of the wheat. The wheat temperature required for a 3-percent decrease in loaf volume in 1 hour varied from 200° F. at 8-percent to 135° at 20-percent moisture content in the wheat.

Thermal conductivity

Buré (116) presented data of Ugrimoff on the thermal conductivity of grain. Grain at 15 percent moisture has a specific heat very close to 0.45. Calculations from the curves of heating and recooling showed thermal conductivity of four samples:

Sample:	Moisture	Thermal conductivity, c.g.s. units
	Percent	
No. 1 Manitoba	11.7	0.00036
Manitoba, damp, moldy	19.5	.00037
No. 1 Northern Manitoba	12.5	.00041
English wheat	17.8	.00039

Cleve and Hoffmann (140) studied heat transfer numbers and heat conductivity numbers in the conditioning of grain. They inserted a constantan-manganin thermocouple into a kernel of wheat to measure the internal temperature. Yellow and red colored powders (Ag_2HgI_4 and Cu_2HgI_4), as well as commercial tempera-

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[7] $\overline{H} = (H/n) = (RT_1\ T_2/T_2 - T_1)\ \ln\ (f_2/f_1)$, where f_2 = relative vapor pressure at the higher temperature (T_2), which corresponds to the same moisture as the relative vapor pressure (f_1) at the lower temperature (T_1).

TABLE 91.--*Internal temperatures and moisture changes in kernels of wheat heated in an air bath at six temperatures*

Time, seconds	Air bath temperature, °C.					
	93	84	77	68	54	49
	Internal temperature of kernel, °C.					
0	20.8	20.3	19.8	20.1	19.8	19.8
15	37.6	35.3	31.8	28.8	25.5	23.5
30	45.8	43.8	37.0	34.5	29.8	27.0
60	56.2	52.0	47.2	43.5	36.8	32.1
120	70.6	---	58.8	52.9	44.5	---
180	78.5	70.5	63.5	57.7	48.5	42.3
240	82.8	75.6	66.4	60.7	50.3	44.1
300	86.0	78.3	68.2	62.3	51.5	45.3
	Moisture content of kernel, percent					
Before heating	16.6	16.7	16.6	16.4	16.6	16.6
After heating	13.3	14.1	14.5	15.1	15.7	16.0

Source: Cleve and Hoffmann (140, p. 58, table 2).

TABLE 92.--*Internal temperatures of a kernel of wheat in a layer of wheat heated by steam*

Time, seconds	Air temperature		Temperature in wheat kernel
	Below sieve	Above sieve	
	°C.	°C.	°C.
0	99.5	26.0	25.1
10	---	---	42.0
20	---	---	76.0
30	99.5	82.0	92.0
45	---	---	96.0
60	99.5	92.0	96.8

Source: Cleve and Hoffmann (140, p. 59, table 5).

ture-color indicators, were used to estimate the temperature of the kernel surface. A considerable difference was found in the rate of heating in dry air and in steam. With steam the first reading at 15 seconds showed the internal temperature of a single kernel to be 100° C. When single kernels of wheat were heated in an air bath, the internal temperature was within 9° of the air bath in 5 minutes. Time of treatment and internal kernel temperatures are given in table 91.

The internal temperature of a layer of grain heated with steam was studied by placing a kernel equipped with an internal thermocouple among kernels in a single layer on a sieve. Temperature of the cold junction was 21.0° and of the room 26.5° C. Steam was passed through the sieve, and internal and air temperatures were recorded (table 92). From these figures heat transfer numbers were calculated. Data are summarized in table 93. Heat transfer numbers, α, are expressed in kcal./m.^{2}/hr./°C.

Schäfer (558) made extensive studies of temperature changes of kernels of hard and soft wheats that were exposed to various temperatures. He measured surface temperatures of the kernels with thermocouples attached to individual kernels that were suspended in a temperature-controlled air-bath. The rate of change in temperature was measured over the range of 20° to 79° C. During the first 15 seconds of heating the hard wheat took up heat faster than the soft wheat. For the next 30 seconds the soft wheat took up heat faster, so that at 1 minute the temperature curves for the two wheats crossed. Later the curves approached each other, so that at

TABLE 93.--*Temperatures of kernels and heat transfer numbers following treatment of single kernels and a layer of grain with steam and with hot air*

Treatment, °C.	Initial temperature	Time	Estimated average final temperature	Temperature inside kernel	Temperature kernel surface	Heat transfer No. (vaporization not considered)
Single kernel:	°C.	*Seconds*	°C.	°C.	°C.	
Steam 100---	46.5	7.5	94.0	92.5	96 (Estimated)	479
Air 84------	20	15	39	35	48	33
Air 77------	20	35	42	33	48	19
Air 67------	20	65	46	44.5	48	17
Air 54------	20	107	45	43	48	18
Grain layer:						
Steam 100---	25	13	58	53	64	50
Air 76------	25	68	43	39	48	7.2
Air 65------	25	107	43.5	40.5	48	6.8
Air 53.5----	25	210	44	58	48	7.8

Source: Cleve and Hoffmann (140, fig. 14).

10 minutes the two wheats had reached the same temperature.

The surface of small light kernels heated up more rapidly than did the surface of large heavy kernels. In Carstens V variety this phenomenon apparently had its basis in a difference in behavior at high temperatures; average values showed no difference when the data at 69° and 79° C. were excluded. Northern spring wheat, however, behaved otherwise; a marked difference in the rate of approach to equilibrium was still apparent when data at the higher temperatures were excluded. Further experiments showed that in air of high humidity, which limited evaporation of water from the kernel, heating of the kernel surface took place much faster.

Schäfer (559) studied the differences in temperature between the surface in the crease and the interior of a wheat kernel by use of thermocouples. He found an average difference between the exterior and the interior of the kernel of 2.5° C. after heating for 10 seconds and of 3° after cooling for 12 seconds. Additional studies were made of contact heating and direct steam heating. Schäfer summarized his results as follows:

1. Surface temperature of a kernel is, at every moment of the heating, a function of the air temperature.
2. Heating of the surface goes on more quickly in moving air than in quiet air.
3. An equilibration of the surface temperature of a kernel with the temperature of the contact surface occurs, in contact heating, within 30 seconds.
4. Heating by steam is comparable to contact heating.
5. Temperature equilibration between any point in the interior of the kernel and the surface occurs within about 30 seconds; heat transfer to the kernel interior is very rapid.

Schäfer stated that in every heat treatment that lasts longer than 10 minutes (the time for equilibration of surface and air temperature) the grain temperature corresponds exactly to the air temperature.

Hoffmann (309) presented extensive tables and graphs useful in the application of some physical laws to grain conditioning and drying. Tables and graphs were given for:

1. Laws of moist air (Dalton).
2. Diagram for moist air at 760 mm. of mercury (Mollier).
3. Vacuum-air pressure vs. temperature of vaporization.
4. Radiation (infrared) (Planck's law).
5. Sorption isotherms for grain.
6. Approximate calculations to determine water extraction, air, and heat demand

during drying; addition of water during dampening; and addition of steam during heating.
7. Diagram for determining the moisture and the true extraction or addition during drying or conditioning of wheat.
8. Temperatures and pressures of air saturated with steam and latent heat of vaporization.

Hoffmann (315) discussed the use of steam in grain conditioning. The thermal transfers and moisture changes accompanying steam treatment follow physical laws. Formulas were given for the calculation of these changes. Hoffman outlined the steps (successive or overlapping) through which grain goes in conditioning with steam as follows:

1. Grain is first heated by contact with the conveyor wall;
2. Heated and moistened by the direct contact and condensation of the steam introduced;
3. Further steamed by the moistening water evaporating from the conveyor wall; and
4. Moistened by direct spray of tempering-cooling water at constant temperature.

Efficiencies of Different Methods of Heating

A primary consideration in the steaming of grain during conditioning is the moisture increase accompanying the rise in temperature. Foerster (197) presented tables giving the temperature rise required for, or which will accompany, a given moisture increase. For example, the addition of 2 percent moisture to grain of 13- to 14-percent moisture content would require a temperature increase of 36° C. by steaming. Thus, if the grain was at 24°, it would attain 60° while reaching 15- to 16-percent moisture content.

Lockwood (393) presented figures on the relative efficiencies of three driers when drying wheat from 20- to 14-percent moisture content. Temperatures given were average figures for usual installations. In the case of the hot-air driers, air entering at around 200° F. would leave at 120°. Thermal efficiency and heat required are given in table 94.

TABLE 94.--*Thermal efficiencies and heat required in drying wheat from 20- to 14-percent moisture content*

Determinations made	Radiator drier	Hot-air drier with circuit heater	Hot-air machine without circuit heater
Exhaust air temperature	*90° F. (32° C.)*	*120° F. (49° C.)*	*120° F. (49° C.)*
Volume of air required to evaporate 1 lb. of water--cu. ft.	715	800	800
Volume of air required to heat wheat--do	0	305	305
Relative humidity of exhaust air--percent	95	35	31
Heat required to evaporate 1 lb. of water--B.t.u.	1,000	1,000	1,000
Heat lost by exhaust air in evaporating 1 lb. of water--do	355	755	755
Heat lost in heating wheat--do	0	0	290
Total heat loss--do	355	755	1,045
Theoretical thermal efficiency--percent	74	57	49
Estimated heat losses in cooling and radiation losses in trunking--B.t.u.	400	800	800
TOTAL HEAT REQUIRED--B.t.u.	1,755	2,555	2,845
Lb. steam/lb. water evaporated	1.8	2.3	2.75
Annual coal consumption--tons	275	385	450
Fan horsepower	18	Approx. 25	33
Total drying time--minutes	110	---	140

Source: Lockwood (393, p. 197, table, and pp. 216, 218, 220).

The heating effects from tempering with warm water are very slight (5). Rich (524) discussed the limited effect possible even with water of 212° F. and compared it with the effects possible with steam. He gave as an example the problem of raising 100 pounds of wheat from 13.5- to 15.5-percent moisture content, which would require the addition of 2.34 pounds of water. Assuming a grain temperature of 72°, the B.t.u. in the boiling water would be only enough to raise the temperature of the grain mass 6.5°. Rich's calculations show that steam can accomplish what hot water cannot, since 970 B.t.u. are given up for each pound of steam condensed to water at 212°. Condensation of 2.34 pounds of steam in 100 pounds of wheat will raise the dampened grain mass from 70.3° to around 120°, resulting in a significantly greater rate of penetration of water into the kernels.

Summary

The specific heat of wheat rises with an increase in the moisture content of the grain and with an increase in the temperature of determination (169, 449, 497, 560); most values reported are between 0.3 and 0.5. The type of wheat was also shown to affect the specific heat (560). Heat denaturation of gluten is a first-order reaction (64). Thermal conductivity of a number of wheats has been determined (116, 140, 449, 558, 559). The rise in temperature of wheat tempered with warm water was shown to be very small in comparison to the rise possible when the same amount of water is added in the form of steam (5, 197, 524). Efficiencies of some driers have been compared (393).

ENTRANCE OF WATER INTO THE WHEAT KERNEL

The structure of the wheat kernel has a direct bearing on absorption of water by the kernel. A description of its gross anatomy may be found in Bradbury, Cull, and MacMasters (102) and in literature cited therein.

Place of Entrance and Movement of Water

A considerable number of workers have attempted to determine the place at which water enters the wheat kernel. Three chief methods of investigation have been used: (1) Determination of moisture increase by weight increase in different parts of the kernel after it has absorbed water, (2) protection of limited portions of the kernels from water absorption and comparison of moisture absorption of these kernels with that of control kernels, and (3) determination of moisture entrance into and movement through the bran and/or starchy endosperm by use of special staining procedures.

Moisture determined by weighing

Eberhardt's report (in 386) of the absorption of water by Polish wheat at 20° C. is representative of the early studies:

Duration of wetting, hours:	Moisture in--	
	Germ part	Brush part
	Percent	*Percent*
12	57.64	47.00
24	64.67	53.57
48	75.33	64.32

Mambish and Demidov (413) gave the following figures for absorption of water by different parts of the wheat kernel; absorption is expressed in percentage of total water absorbed (time for absorption not stated):

Kernel portion:	Total water absorbed
	Percent
Beard end	4
Middle section near beard end	19
Middle section near germ end	20
Germ end	57

Ugrimoff (635) showed graphically the average moisture content of the beard half and the germ half of a vitreous North African wheat after immersion of the uncut kernels for different periods of time at room temperature. He used 40 kernels for each analysis. The following data were taken from his graph (635, fig. 532):

Duration of immersion, hour(s):	Water content in--		
	Beard half	Uncut kernel	Germ half
	Percent	*Percent*	*Percent*
0.5	13.5	14	14.8
1	13.8	15	17.5
2	15.8	19.5	21.5
3	16.0	21.0	23.8
4	19.0	22.2	26.4
6	20.5	24.5	29.5
8	21.0	27.0	31.0
10	25.0	28.5	35.0
15	27.8	31.8	37.8
19	30.8	35.8	40.5
23	31.8	37.0	41.0

In a somewhat similar experiment, Ugrimoff removed the germ from the soaked kernel and obtained moisture determinations on the germ, the germ half without the germ, and the beard half. He computed the moisture content of the germ half plus the germ from the data, through consideration of the relationship of the weight of the germ to the germ half of the kernel. The following data were taken from his graph (635, fig. 533):

	Water content in--			
Duration of immersion, hour(s):	Beard half	Germ half without germ	Germ half with germ (computed)	Germ
	Percent	*Percent*	*Percent*	*Percent*
0.5	10.8	11.9	12.1	21.9
2......................	13.0	15.5	16.3	29.0
5......................	17.2	22.8	24.5	43.6
18	28.0	35.0	37.2	58.0

Ugrimoff concluded that during total immersion of the kernels in water at 17° to 18° C. the germ portion of the kernel absorbed water much more quickly and in a greater amount than did the beard portion. He also stated that fracture lines in the vitreous kernels played some part in conducting the water into the endosperm.

Filter (in 386) compared the water absorption ability of dissected embryos and similar-sized pieces of endosperm of wheat at 20°C. in a vapor-saturated room. Water absorption by the embryo was 20 and 45.4 percent after 4 and 24 hours, respectively, and by the endosperm was 7.1 and 15.3 percent.

Selective exposure of kernel parts

Swanson and Pence (626) shellacked different portions (approximately equal in area) of Kanred variety wheat kernels that were picked from the head by hand. The kernels were placed between wet layers of muslin and at intervals some kernels were removed, blotted to eliminate surface water, and weighed. Gains shown by the kernels after specified times were as follows:

	Gains after--				
Treatment:	1 hour	2 hours	4 hours	6 hours	24 hours
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Check	5.8	8.5	13.8	18.4	40.0
Shellac on brush	6.3	9.3	14.1	20.8	37.8
Shellac on back..	4.3	6.9	10.5	14.1	32.0
Shellac on germ	4.1	6.2	9.3	12.6	29.7

Swanson and Pence concluded that very little, if any, absorption took place through the brush end, but they pointed out that this would not be true for kernels that had been threshed or scoured. They considered that their results contradicted the theory that water enters the grain only through the germ.

Campbell (120), too, conducted experiments on absorption of water by kernels that had certain portions waterproofed. He reported the following uptake of water (in percentage of the initial weight of the grain) by Marquis wheat during 1 minute's immersion: Nonwaterproofed, 3.42 percent; germ-end-proofed, 3.07 percent; and beard-end-proofed, 3.23.

Moisture determined by staining

Haltmeier (292) immersed wheat kernels in a dilute solution of potassium thiocyanate for different periods of time, rinsed the kernels and cut them across or longitudinally, and then sprayed the cut surfaces with a dilute solution of ferric chloride. Formation of a red color indicated the presence of potassium thiocyanate, therefore moisture, in the colored area. From his experiments and observations Haltmeier concluded that the initial penetration of water into the kernel occurred at the outer edge of the boundary between the germ and the floury endosperm. From this boundary, moisture moved slowly toward the brush end and moved more rapidly in the vicinity of the bran than in the middle of the kernel. The endosperm was colored throughout only after 20 to 25 hours. Water entered kernels immersed at the brush end, but the potassium thiocyanate was held back for several hours. The germ was not colored red unless the tempering time was very long. Haltmeier concluded that potassium thiocyanate solution could enter only around the edge of the germ, whereas pure water could pass through the bran coat.

Schroeder (581a), while investigating the selective permeability of the outer coverings of the wheat kernel, obtained some evidence that the germ is the place of entrance of water. The starchy endosperm of kernels immersed in a dilute iodine-potassium iodide solution showed blue color first in the immediate vicinity of the germ. With longer immersion the color spread toward the brush end more quickly on the dorsal than on the ventral side of the kernel. An increase in the concentration of iodine from 1/10,000 N to 1 N increased the speed of forward movement of the blue color. Similar results were obtained when a wheat kernel was placed with only the germ end in gelatin impregnated with iodine. When the brush end, only, was placed in the iodine-gelatin, no uptake of iodine occurred. When halves of transversely bisected kernels were impregnated with cobaltous chloride, dried, and then immersed in water, the color change indicated the entrance of water into the germ half on the cut surface and also in the vicinity of the germ, but entrance into the brush half only from the cut surface.

Ugrimoff (635) followed the penetration and movement of water into and within the starchy endosperm of immersed wheat kernels by bisecting the kernels after various periods of immersion, exposing the kernel halves to iodine vapor, and observing the color of the endosperm. Although he prepared a table showing the color taken on by samples of middlings of known moisture contents from 10 to 25 percent, he stated that in observations of the kernel endosperm it was possible to say with certainty only that the moisture content was less than 16 percent if the endosperm was yellow, and more than 22 percent if dark lilac to black. His experiments with total immersion of kernels were made with a completely vitreous North African wheat of about 9-percent moisture content. The temperature of the immersion water was from 18° to 20° C. He stated that the rate of entrance varied greatly from kernel to kernel and that this variation was greater within a variety than between varieties. Tabulation was made from his descriptions and diagrams, all of which were based on average results:

Immersion time, hours:	Appearance of median longisection cut parallel to crease
1.5	Small black spots in angle where tip of germ meets back of grain and in angle where base of germ meets crease.
3	A narrow black band separates germ from light-colored endosperm.
4	Black band is wider and extends upward along back of kernel.
5.5	Black area covers 1/3 to 1/2 of entire endosperm from germ upward.
7	Upper part of kernel (beard end) has darkened.
9	Entire endosperm is black.

Ugrimoff (635) also conducted experiments with partially immersed kernels; either the beard end or germ end was immersed in water. The kernels were suspended by thin wires or, for mass tests, placed in small holes in a cork slab. The surface of the unimmersed portion of a kernel remained dry. The moisture of uncut kernels suspended above water (18° C.) rose from 8.97 to 9.40 percent in 24 hours and to 9.60 percent in 7 days, thus indicating negligible absorption of moisture from the air immediately above the water. Results of two experiments are given in tables 95 and 96.

Absorption of water by kernels whose germ end was immersed, ceased after about 5 hours. At that time one-third to one-half the endosperm above the germ was colored black by the iodine test. The kernels germinated and, in 7 days, the shoot was usually 2 or more inches long, The beard end of kernels whose beard end was immersed in water showed a dark color with iodine only after 11 to 12 hours. This stage of moisture absorption was reached 3 to 4 hours earlier in kernels that had been completely immersed. The kernels whose beard end only was immersed did not germinate even in 30 days. No matter which end of the kernel was immersed, the part above the water remained hard and vitreous.

Ugrimoff concluded that at room temperature water enters the kernel chiefly through the germ or in its vicinity, that mellowing of the endosperm occurs first near the germ and gradually spreads toward the beard, and that water is absorbed in smaller amounts and more slowly through the entire surface of the kernel.

Buré and Cosse (119) repeated the work of Ugrimoff. Buré (115) stated that their results confirmed and complemented the conclusions of Ugrimoff. They found much more rapid penetration of water into the kernels, but they were using French wheats and a Marquis wheat. By the fourth hour of total immersion at 20° C. the water which entered at the area of contact between germ and endosperm had already penetrated half of the endosperm. After 2 or 3 hours, entrance over the entire surface of the kernel was noted. If only the brush end of the kernel was immersed, entrance over the entire surface did not begin until after 5 to 8 hours of immersion.

Jones (342) used the iodine method in experiments on water absorption by No. 1 Manitoba wheat immersed in water at

TABLE 95.--*Moisture of germ half and beard half of wheat kernels that had only germ or only beard end immersed for designated number of hours*

Immersion conditions	Kernel half	North African wheat A 10.44% moisture		North African wheat B 8.8% moisture		Hard winter wheat 10.34% moisture		Domestic wheat 11.82% moisture	
		1 hour	8 hours	1 hour	8 hours	1 hour	8 hours	1 hour	8 hours
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Germ end in water	Germ (lower)	14.77	27.91	16.10	26.68	17.91	29.51	14.18	29.89
	Brush (upper)	11.77	15.04	9.65	11.56	11.46	15.29	12.61	15.62
Brush end in water	Germ (upper)	11.60	15.60	9.13	13.60	12.00	16.96	11.77	14.76
	Brush (lower)	12.60	18.81	10.62	17.05	13.11	19.03	13.60	18.57

Source: Ugrimoff (635, p. 626, table II).

TABLE 96.--*Moisture of germ half and beard half of North African wheat kernels that had been partially immersed in water for the designated periods*

Duration of wetting, hours	Moisture content				Remarks
	Germ end in water		Beard end in water		
	Beard end	Germ end	Beard end	Germ end	
	Percent	*Percent*	*Percent*	*Percent*	
24	13.62	34.95	25.05	16.13	Normal wetting, the kernels were cut at edge of glassiness.
24	17.10	37.20	24.64	19.10	Normal wetting, the kernels were cut in the middle.
48	16.45	38.31	26.96	16.18	Normal wetting, the kernels were cut at edge of glassiness.
112	13.40	65.50	26.50	15.40	The kernels were immersed only a little in water and cut at the edge of glassiness.

Source: Ugrimoff (635, p. 626, table III).

60° C. The diagrams given for whole kernels in his figure 3 are in close agreement with the results of Ugrimoff. Decorticated grains, in which all endosperm except that in the crease was exposed, were penetrated much more quickly by water than were whole kernels; penetration of decorticated grains was greater on the back and at the sides of a kernel than on the faces of the cheeks. Transections cut near the middle of the grain and near the germ showed this same pattern of absorption.

Hopf (320) concluded from experiments in which water vapor at 149° to 158° F. was applied locally through a small tube to the crease, back, brush, and germ, that entrance of water was through the germ. He attributed slight mellowing of the endosperm following application of the water vapor at the crease and at the brush, to the effect of heat in combination with the internal moisture of the kernel. When vapor was applied for 6 minutes to the back of the kernel, no mellowing occurred at the place treated, but there was slight mellowing along the scutellum and up the crease. This mellowing was attributed to passage of water through the bran, thence to the germ, and then along the usual path from the germ. Mellowness was determined by probing and, by inference, from coloration with iodine.

Molenarius (447) used the iodine method, supplemented by maceration of tissue, for studying the entrance of moisture into wheat kernels. He tempered Manitoba wheat with 5 percent water. After 4 hours about a third of the endosperm had been mellowed, but the location of the mellowed tissue was not as reported by Ugrimoff and Buré. Instead, the mellowed portion was around the germ, around the crease for the length of the kernel, and at the beard end. After 24 hours the only portion of the endosperm not mellowed was a small area at the back of the kernel.

Grosh and Milner in 1955 (282) reviewed the subject of the penetration of moisture into the wheat kernel and in 1958 (283) presented results of a study on water penetration and internal cracking in tempered wheat grains. They stated that cracks were formed in vitreous endosperm of tempered wheats in advance of water movement through the kernels. They suggested that the cracks induced by wetting form the middlings which are released during milling.

Capillary tube theory

Fritsch (203, 204, 213, 218) and Fritsch and Cleve (223) studied in several ways the problem of entrance and movement of moisture in the kernel. In some experiments he placed once-soaked kernels under oil, pressed them gently, and observed that a succession of air bubbles came from the region of the kernel by which it had been attached to the spike (204). He assumed that capillary tubes led from this area into the interior of the kernel and that they could be used for the entrance of water. The evacuation of normally dry grain preceding its immersion in water (in outer-layer treatment) was based on the idea that these capillary tubes would conduct water better if the air were removed. Fritsch and Cleve (223) stated that this vacuum treatment also brought about the rupture of cell walls, especially those of the aleurone layer. It also caused breaking between various layers of the kernel: between germ and scutellum, scutellum and endosperm, and aleurone layer and kernel coat. Fritsch (204) also stated that water entered through the coat of the kernel when heat and moisture were applied together. Fritsch (213) wrote at some length of a hyaline system concerned in the transport of water in the kernel. He described this as a thin layer traversed by a microscopic network of tubes that opened to the exterior in the vicinity of the germ. He may have referred to the vascular strand in the attachment region.

Gehle (239) held that water entered the kernel first by the germ, then by the beard, and finally by the crease. He stated that the cell walls behaved like blotting paper conducting water by capillary action.

Moisture determined by endosperm density

Campbell and Jones (121, 122, 123) and Jones and Campbell (345) have published results of fundamental research on the physical basis of the response of endosperm density to changes in moisture content and also on rates of penetration of moisture to different parts of the endosperm. They found that at 20° C. penetration was most rapid into the back and shoulders of the kernel (prismatic-cell region) and that the cheek centers (rounded-cell regions) were the last to reach the final level of moisture (123).

Factors Affecting Rate of Entrance

Time and temperature

Jones (342) in 1949 summarized previous studies on the rate of penetration of water into the wheat grain and also discussed his own experiments. Most of the results published before that time (168, 201, 292, 295, 304, 466, 626) were in agreement with, or at least did not conflict with, Jones' statement concerning the three stages of absorption by a kernel during immersion at 60° F. These conclusions were based on his graphically presented results of experiments that extended for 3 hours:

"1. A rapid initial pick-up of 4-5 percent water.

"2. An immediately following fairly short period, from about 2-12 min., during which the rate of pick-up is falling. . . .

"3. A long period of much slower but relatively steadily maintained absorption." In this period the relation of pickup to time of immersion is nearly linear.

Jones concluded that the rapid pickup during stage 1 was the result of absorption of water by the outer layers of the bran and that the hyaline layer was a temporary barrier to further absorption. Later Hinton (305) stated that the testa was the barrier layer.

Campbell (120) attributed the variation from 3.0 to 4.9 percent in the pickup of water by various samples of English and Canadian wheats during 1 minute's immersion to a variation in the extent of pericarp damage and in the initial moisture content of the samples. Evidence for the effect of the latter factor was presented in a graph.

Investigations by several workers (168, 295, 342, 626) who immersed kernels in water at 6° to 50° C., have shown that stage 1 is essentially unaffected by heat but that stages 2 and 3 are markedly affected. Swanson and Pence (626) used a uniform lot of hard wheat in studying the effect of temperature on the rate of absorption of water. Both the wheat and the water in which it was immersed were heated or cooled to certain temperature before the immersion. Samples were taken from the water at definite intervals, centrifuged to remove excess water, and then weighed (table 97). The ratio of deviation from the mean to the probable error shows that temperature had a decided effect upon the rate of absorption of water if immersion periods were longer than 2 minutes. It is apparent from table 97 that absorption of water was faster at higher temperatures.

Haltmeier (295) studied the rate of water absorption by 100-gram samples taken from two different harvests of the same German wheat. He, also, immersed the samples, centrifuged them after certain periods of time, and determined water absorption. His results (table 98) show, like those of Swanson, that after a few minutes' immersion the absorption of water was faster in water at a higher temperature.

Dillman (168) measured the rate of water absorption of a plump, air-dry, Marquis wheat at 10° and at 25° C. Twelve-gram samples of the immersed wheat were re-

TABLE 97.--*Effect of temperature on the rate of absorption of water by a hard wheat*

Period of immersion	Water absorbed per 100 grams of wheat at--						Largest deviation	D/P.E.[1]
	6° C. 42.8° F.	27° C. 80.6° F.	40° C. 104° F.	60° C. 140° F.	80° C. 176° F.	Mean		
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	
Instant dipping	4.1	4.5	3.4	4.1	4.1	4.04	0.64	0.86
Seconds:								
10------------	4.1	5.1	4.6	4.4	4.7	4.62	.52	.70
20------------	4.6	5.6	5.0	4.5	5.3	5.0	.6	.81
40------------	5.4	6.5	5.1	4.9	5.6	5.5	1.0	1.34
Minute(s):								
1-------------	5.5	7.3	7.4	5.7	6.8	6.54	1.04	1.40
2-------------	5.6	7.7	8.4	7.2	9.0	7.58	1.98	2.66
5-------------	5.7	8.9	10.0	10.0	14.1	9.54	4.56	6.12
10------------	6.2	9.9	11.7	14.7	22.1	---	---	---
20------------	6.9	12.0	15.7	20.5	33.7	---	---	---
40------------	9.1	14.3	19.9	29.5	48.7	---	---	---
90------------	10.6	18.6	28.6	45.5	---	---	---	---
Hours:								
2-------------	12.5	21.1	32.2	49.7	---	---	---	---
3-------------	14.3	24.4	36.6	---	---	---	---	---
4-------------	15.4	29.6	40.7	---	---	---	---	---
6-------------	20.1	33.2	45.3	---	---	---	---	---
8-------------	23.5	38.4	49.1	---	---	---	---	---
18------------	24.7	43.5	---	---	---	---	---	---
24------------	27.8	50.4	---	---	---	---	---	---
48------------	35.8	---	---	---	---	---	---	---

[1] Ratio of deviation from the mean to the probable error.

Source: Swanson and Pence (626, p. 435, table II).

TABLE 98.--*Effect of time and temperature of immersion on water absorption by a German wheat*

Time, minutes	Weight at--	
	20° C.	50° C.
	Grams	*Grams*
0	100.0	100.0
.5	109.1	---
1	---	109.5
2	---	110.7
3	111.1	---
4	---	112.4
5	112.0	---
6	112.2	---
10	112.4	---
11	---	115.2
27	114.2	---

Source: Haltmeier (295, table).

moved after various periods of time, drained, rolled between dry towels, rubbed dry between blotters for 1/2 minute, put in closed aluminum trays, and weighed. Since Dillman's first sample was removed after 2.5 minutes, his data (table 99) are concerned only with stages 2 and 3. They show that absorption of water was more rapid at 25° than at 10°.

A negligible effect of temperature on stage 1 and its appreciable effect on stages 2 and 3 up to a 3-hour period of immersion were shown by the graphic data of Jones (342). He compared the absorption by Manitoba 1 wheat immersed in water at 80° F. with that when the water was 60°. The pickup of water was determined after centrifuging to obtain a centrifugal effect of 1,000 G.

Herd (304) conducted two experiments to determine the effect of heat on moisture absorption by wheat. The samples of wheat were suspended in water, drained, freed of surface water by whirling them in cloth con-

TABLE 99.--*Rate of absorption of free water by wheat seeds at temperatures of 10° and 25° C. at intervals from 2.5 minutes up to 48 hours*

Interval	Moisture content at--		Gain from initial moisture content at--			Ratio of gain at 25° C. to gain at 10° C.
	10° C.	25° C.	10° C.	25° C.	Difference	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	
Initial sample	[1] 11.9	10.8	---	---	---	---
Minutes:						
2.5	16.8	16.7	4.9	5.9	1.0	1.20
5	18.2	17.8	6.3	7.0	0.7	1.11
10	18.8	19.8	6.9	9.0	2.1	1.30
20	20.3	21.5	8.4	10.7	2.3	1.27
30	21.6	23.7	9.7	12.9	3.2	1.33
60	24.0	27.5	12.1	16.7	4.6	1.38
Hours:						
2	27.9	34.4	16.0	23.6	7.6	1.47
3	31.6	38.4	19.7	27.6	7.9	1.40
4	34.2	42.5	22.3	31.7	9.4	1.42
6	38.5	49.7	26.6	38.9	12.3	1.46
8	43.4	54.7	31.5	43.9	12.4	1.39
10	---	59.5	---	48.7	---	---
22	---	69.9	---	59.1	---	---
24	59.2	71.2	47.3	60.4	13.1	1.28
48	70.2	81.9	58.3	71.1	12.8	1.22

[1] This sample of wheat was held at 10° C. for 16 hours in a damp refrigerator where it absorbed some moisture as compared with the sample used at 25° C.

Source: Dillman (168, p. 68, table 4).

tainer, and stored in stoppered containers. In the first experiment immersion times of 0.5 and 2 minutes in water at 66° and 86° F. were used. Moisture was determined in a Hearson electric oven at 120° C. for 1.5 hours. The amount of water absorbed by the different samples, given in grams of water absorbed per 100 grams of wheat, were (304, p. 715, table 3) as follows:

	Water absorbed at--			
	66° F. after--		86° F. after--	
	0.5 min.	2 min.	0.5 min.	2 min.
Wheat:	*Grams*	*Grams*	*Grams*	*Grams*
English	2.8	2.8	3.1	3.5
Australian	3.4	4.1	3.5	4.5
Danubian	3.5	4.6	3.9	5.1
Plate	3.8	4.9	4.3	5.8
Manitoba 1	4.2	4.3	4.5	4.6
Manitoba 4	4.5	5.4	4.4	5.9
Persian	4.3	5.3	5.1	5.5
Manitoba 5	5.1	6.2	5.3	6.5
Latvian	5.5	6.3	6.8	5.9

Herd noted the slight increase in absorption caused by the higher temperature but considered it of little practical significance. In his second experiment, temperatures of 66° and 120° F. were used and the rate at which equilibration of moisture occurred was determined by use of a "D.E." meter. Equilibration was indicated by approximately equal successive moisture readings. Results show that the distribution of water was hastened by the higher temperature (304, p. 716, table 8) as follows:

Time,	No. 1 Manitoba		Persian		Danubian	
hour(s):	*120°F.*	*66°F.*	*120°F.*	*66°F.*	*120°F.*	*66°F.*
1	> 29.0	> 29.0	> 29.0	> 29.0	> 29.0	> 29.0
2	24.0	27.9	17.9	29.0	23.0	29.0
3	---	---	16.0	---	18.0	---
4	20.6	25.3	15.8	21.6	17.9	22.9
5	20.0	23.6	15.8	18.4	17.7	20.4
6	20.0	23.4	15.6	17.6	---	19.4

Haltmeier (292) studied the effect of temperature on the rate at which moisture became uniformly distributed through kernels of wheat. He added 2 percent water to samples of Manitoba wheat and German domestic wheat. Half of each sample was kept at room temperature (68° F., 20° C.) and the other half was kept at 104° F. (40° C.) for 1.5 hours and then cooled to room temperature. At intervals the moisture content of the grain was measured with the "DK" apparatus (table 100). Approximate equilibration was reached more quickly in the heated samples than in those kept at room temperature.

With a "Beha" electric moisture meter, Ward (647) followed the approach to equilibrium of moisture in wheats which were damped at room temperature and kept in stoppered bottles, or conditioned in a laboratory hot-air circuit conditioner at temperatures of 110° and 150° F., respectively. His results (table 101) indicated that an even distribution of water was attained in about one-third of the time at 110° as at room temperature, and in about one-half the time at 150° as at 110°.

Nuret (466) illustrated graphically in his figure 4 that the amount of water absorbed by two varieties of French domestic wheat was somewhat increased when the temperature of the immersion water was raised from 10° C. to 40° C.

Simon (595) presented data that showed the difference at three temperatures in the rate of absorption of water by Manitoba wheat with 18-percent internal moisture content and 0.5- to 1-percent surface moisture retained after washing and whizzing (table 102). An increase of 0.5-percent moisture content required 90 minutes at 60°, 36 minutes at 100°, and 30 minutes at 130° F.

Buré (115) and Jones (342) studied by the iodine method the effect of heat on the rate of entrance of water into immersed grain. Buré immersed kernels in water at 35°, 50°, 70°, 85°, and 100° C., and subjected kernels to free steam and to steam under slight pressure. He presented diagrams from earlier work by Buré and Côsse and also gave the following summary of results:

> At 35° C., water penetrates through the germ, beginning in 15 to 30 minutes, then through the brush zone and finally through the rest of the surface of the grain.
>
> At 50°, water penetrates by way of the germ, beginning at 10 to 15 minutes. Penetration at the brush zone begins almost as rapidly but the intensity of coloration is less. The water then progressively penetrates through the rest of the surface.
>
> From 70° to 100°, the penetration is even more rapid. Water penetrates through the entire surface from the 10th minute at 70° and in only 1 to 2 minutes at 100°.
>
> On the other hand, when the grain is held in free steam, humidification requires 45 minutes; the penetration is reduced to 5 minutes when the steam is under low pressure.

TABLE 100.--*Effect of time and temperature on moisture equilibration in wheat as determined by the "DK" apparatus*

Time		German wheat		Manitoba wheat	
Hour(s)	Minutes	Cold	Warm	Cold	Warm
		Percent	*Percent*	*Percent*	*Percent*
0------------	---	14.2	14.2	11.1	11.1
1------------	10	17.2	---	15.2	---
1------------	45	16.9	Cooled	14.5	Cooled.
2------------	18	---	16.2	---	13.9
3------------	05	16.6	16.0	14.1	13.7
4------------	50	16.5	---	14.0	---
9------------	---	16.0	15.9	13.7	13.6
48------------	---	16.0	16.0	13.7	13.5

Source: Haltmeier (292, p. 38, table 1).

TABLE 101.--*Moisture indicated by "Beha" electric moisture meter for three dampened wheats during attainment of equilibrium*

Wheat and temperature, °F.	Moisture after --					
	2 hours	4 hours	6 hours	12 hours	48 hours	72 hours
Manitoba:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Cold----------	19.4	19.1	18.9	18.8	18.5	18.4
110°----------	18.5	18.3	18.3	18.2	---	---
150°----------	18.6	18.6	---	---	---	18.6
Plate:						
Cold----------	18.2	17.9	17.8	17.4	17.3	17.3
110°----------	17.65	17.5	17.4	17.4	---	---
150°----------	18.0	17.9	17.9	---	---	17.9
Australian:						
Cold----------	16.9	16.6	16.5	16.5	16.15	16.1
110°----------	16.1	16.05	15.9	15.9	15.9	15.8
150°----------	16.0	16.0	---	---	---	16.0

Source: Ward (647, pp. 6, 7).

The diagrams and statements agree in general but not in all details. The diagrams show that water had penetrated throughout the endosperm in 8, 6, 5, 0.75, 0.25, 1.25, and 0.5 hours, during respective immersions at 20°, 35°, 50°, 70°, and 100° C., and exposure to free steam and to steam under pressure.

Jones (342) immersed kernels of No. 1 Manitoba wheat in water at 65°, 110°, and 140° F. His diagrams showed that the first evidence of water penetration near the germ was after 90 minutes at 65° F., but after only 20 minutes at 110°. The degree of penetration reached in 90 minutes at 110° was reached in about 50 minutes at 140°. The rate of penetration through the endosperm of decorticated kernels was also increased at the higher temperatures. Jones called attention to the fact that an increase in penetrability of the entire surface of the kernel was brought about by the higher temperatures.

Investigations of Fritsch (218) are of interest in connection with the effect of heat on the penetrability of the entire surface of

TABLE 102.--*Effect of temperature on absorption of moisture by wheat with 18-percent internal moisture content and varying amounts of external moisture*

Time heated, hour(s)	60° F. and 0.8-percent surface moisture	100° F. and 1-percent surface moisture	130° F. and 0.5-percent surface moisture
	Percent	*Percent*	*Percent*
0-------------------------	0	0	0
.25-----------------------	.1	.3	.2
.5------------------------	.2	.2	.5
.75-----------------------	.3	.7	---
1.0-----------------------	.3	.8	---
1.25----------------------	.4	1.0	---
1.5-----------------------	.5	---	---
Rate of absorption, percent per hour-----------------	0.32	0.80	0.95

Source: Simon (595, p. 90, table I).

TABLE 103.--*Permeability to water of the isolated testa as measured by the time of formation of drops that passed through it*

Testa isolated from --	First drop formed after	Second drop formed after
	Hours	*Hours*
Domestic soft wheat-------	15	3
Domestic hard wheat-------	19	4
Domestic soft wheat as usually conditioned[1]----	4	1
Domestic hard wheat as usually conditioned[1]----	4.5	1.2
Domestic hard wheat treated with steam------	1	.4
Domestic wheat, slightly sprouted.---------------	5	.5
Manitoba wheat------------	28	8.5

[1] It is inferred from the text that the temperature was about 40° C.

Source: Fritsch (218, p. 54).

the kernel to water. Fritsch, testing the permeability of the isolated testa (seedcoat) in unconditioned and conditioned wheat, found (table 103) that conditioning increased the permeability of the testa.

Schäfer (551) compared the effect on water absorption of moistening a German domestic wheat by immersion in water at 20° C. and at 40° C. and by treatment with steam. Water content of whole kernels was determined by the usual weighing procedure; that of the endosperm by the iodine method. Results were presented graphically. Approximate figures taken from graphs (p. 196, figs. 7-9) indicate the effect of heat on rate of absorption:

	20° C., minutes	40° C., minutes	Steam, minutes
Time in which moisture content of--			
22 percent was reached by kernel.	60	40	---
14 percent was reached by endosperm................................	180	30	3

Schäfer (556) concluded from microscopic studies that the rapid entrance of water into the steam-heated kernels was caused by structural changes in the aleurone layer. He inferred that the high temperature brought about denaturation of the protein in the aleurone cells and thus destroyed their ability to regulate the passage of water.

Research on the effect of heat on the rate of entrance of water into the wheat kernel was carried on by Campbell and Jones (121). Data in table 104 apply only to kernels of Manitoba wheat which remained vitreous after they were moistened to 17.2 percent and exposed to the selected temperature. As the authors pointed out, they show that between 20° and 43.5 °C. a rise of 12° causes a threefold increase in speed of movement of moisture to the cheek center.

Another experiment by the same authors, using the same methods, showed how the standing time at 20° C., which is necessary to achieve a certain amount of moisture penetration, was reduced by preheating at 43.5° C. (table 105).

TABLE 104.--*Time required to attain, at three temperatures, three levels of water penetration into vitreous Manitoba wheat kernels dampened to 17.2 percent by immersion and centrifuged to remove free water*

Temperature °C.	°F.	Portion of final moisture increment attained: 50 percent	85 percent	100 percent
		Hours	*Hours*	*Hours*
20.0	68	5	24.0	60
31.5	89	2	8.0	20
43.5	110	< 1	2.6	6

Source: Campbell and Jones (121, p. 136).

TABLE 105.--*Time required for moisture content in central cheek endosperm of wheat kernel to reach 50, 85, and 100 percent of final increment during standing at 20° C. following heating at 43.5° C.*

Initial period at 43.5° C., hour(s)	Portion of final moisture increment attained: 50 percent	85 percent	100 percent
	Hours	*Hours*	*Hours*
0	5	24	60
.5	4	26	60
1.0	---	10	28
2.0	---	3	8

Source: Campbell and Jones (121, p. 138).

Centrifugation

Jones (342) discussed the effect of differences in the centrifugal force applied following immersion on the pickup of water by wheat. Pickup was defined as "the residuum of firmly held water left after centrifuging the wheat." Jones found that pickup fell with an increasing centrifugal effect up to 1,000 G, an effect roughly equalled by rolling wet grains fairly firmly between blotting paper. He also found that results with a commercial whizzer were equivalent to those obtained in the laboratory with no air current and a centrifugal effect of 250 to 300 G. Jones gave data obtained at 60° F. with Manitoba 1 wheat (13-percent moisture content) when short immersion periods were followed by a subsequent application of a centrifugal effect of 1,000 G with the laboratory centrifuge. He found that after immersion periods of 4, 10, 15, 30, 45, and 60 seconds, the respective pickup was 1.2, 2.4, 2.7, 3.2, 3.5, and 3.7 percent of the initial weight. Jones pointed out that reports of a higher pickup than his data show (e.g., Haltmeier (295), Swanson and Pence (626), and Fraser and Haley (201)) were probably due to less vigorous centrifugation and perhaps to a relatively long period between immersion and full application of centrifugal force.

Scouring

Fraser and Haley (201) tested the effect of scouring on absorption of water. They passed wheat samples twice through a laboratory scouring machine set so that the physical appearance of the grain was materially changed and its test weight raised about 2 pounds per bushel. Scouring greatly increased the amount of water absorbed by samples immersed for 1 minute in water at 56° F., centrifuged for 30 seconds in a basket 2 inches in diameter at 3,200 r.p.m., and weighed. The wheat, treatment, and gain in weight were as follows:

Wheat:	Treatment	Gain in weight, g./10-g. sample
Marquis	Not scoured	0.48
Marquis	Scoured	.77
Turkey	Not scoured	.47
Turkey	Scoured	.56
Fortyfold	Not scoured	.41
Fortyfold	Scoured	.72

Campbell (120) found that the pickup of water by Marquis wheat kernels during 1 minute's immersion was greatly increased by scouring. By waterproofing some scoured kernels on the beard end and some on the germ end prior to immersion, he determined that this additional pickup resulted from a localized entry of water at the beard end of the kernel (table 106). The moisture contents of beard and germ ends of bisected grains showed that the additional water absorbed by scoured kernels was held at the beard end during the first 4 minutes after wetting and became distributed nearly equally between the two halves of the kernel within 12 minutes (table 107).

The extent of water travel away from the beard end beneath the pericarp on the dorsal surface was inferred from the staining obtained after holding a kernel with the beard end just in contact with a 0.1-percent solution of methyl orange in methanol for 1 minute. The extent of staining was rather directly related to the weight of water picked up following immersion during wheat washing. Experiments indicated that wheats subjected to considerable commercial handling had a greater water pickup and staining score than wheats subjected to less handling. The former wheats also showed a greater increase in water pickup and staining score after scouring than did the latter.

The rate of water penetration into the endosperm of scoured Manitoba wheat was compared with that for unscoured wheat. An increase in the rate of water penetration in the scoured wheat, as determined by endosperm density measurement, was apparent only near the bran at the back of the kernel. In that area moisture-content equilibrium was reached in 5 hours in scoured wheat in comparison with 15 hours in unscoured wheat.

Internal fissures

Fisher and Hines (192) found some evidence for the formation of fine cracks, or the enlargement of pre-existing cracks, during moistening of wheat or during drying. They were attempting to determine the rate of penetration of water into wheat by measuring the change in volume of a mixture of water and wheat. They noted that when the wheat had been moistened or oven-dried, the initial expansion in volume, compared with that of normal wheat, was greatly reduced or totally lacking and the subsequent volume shrinkage was greater and more rapid. This phenomenon they attributed to a more or less rapid filling of cracks with water. In one experiment with mixed Manitoba wheat two temperatures were used. The rate of volume shrinkage was greater at 37.5° than at 25° C. for the first 15 to 20 hours, but from then to 6 days the reverse was true.

Milner and Shellenberger (442) found that Pawnee variety wheat subjected to alternate wetting and drying so that the kernels showed extensive internal fissuring similar to that characteristic of naturally weathered grain, absorbed more water in a given time than did untreated, unfissured grain. The differences in absorption (table 108) were statistically significant.

Kernel size

Studies of the effect of various kernel characteristics on the rate or amount of water absorption have been carried on by many workers. An early and important contribution in this field was made by

TABLE 106.--*Effect of scouring of Marquis wheat on the uptake of water during 1 minute's immersion of grains with localized waterproofing treatment*

Treatment	Uptake of water by grain[1]				
	Successive scourings			Increase due to 1 scouring (B-A)	Increase due to 6 scourings (C-A)
	None (A)	One (B)	Six (C)		
Nonwaterproofed-------------------	3.42	4.50	5.55	1.08	2.13
Germ-end-proofed------------------	3.07	3.98	4.86	.91	1.79
Beard-end-proofed-----------------	3.23	3.34	3.97	.11	.74

[1] Expressed as percentage of the initial weight of the grain.

Source: Campbell (120, p. 51, table I).

TABLE 107.--*Effect of scouring on the moisture content of corresponding germ and beard halves of Canadian Marquis wheat (initially at 13.2 percent moisture content) following transverse bisection after different short periods following 1 minute's immersion in water*

Time interval between centrifuging and cutting, minutes	Moisture content[1]				
	Uncut grains	Half grains			Difference between beard and germ ends
		Beard ends	Germ ends	Average of beard and germ ends	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Unscoured wheat:					
4	16.0	15.9	15.9	15.9	nil
6	16.0	16.0	15.9	15.95	.1
12	16.0	16.0	16.0	16.0	nil
Scoured wheat[2]:					
4	16.8	17.4	15.9	16.65	1.5
6	16.7	17.2	16.1	16.65	1.1
12	16.9	17.0	16.7	16.85	.3

[1] Estimated by means of microdensity determinations on particles of endosperm dissected from the central cheek after the grains or half grains had lain under oil for 72 hours at 20° C.

[2] Passed once through the laboratory scourer.

Source: Campbell (120, p. 52, table II).

TABLE 108.--*Influence of internal fissuring on water uptake by wheat*

Time of soaking, minutes	Moisture content[1]	
	Normal	Fissured
	Percent	*Percent*
5	14.2	16.3
15	17.9	17.2
20	18.3	19.6
30	19.3	19.9
35	20.5	20.3
40	19.7	21.6
45	20.2	22.0
50	21.9	23.6
55	21.2	22.7
60	22.6	23.5
65	22.7	24.5
70	22.2	24.0
80	23.1	25.3
90	22.9	25.7
120	25.9	27.9

[1] Mean for duplicate determinations.

Source: Milner and Shellenberger (442, p. 209, table V).

Nuret (466). He established that kernel size as well as immersion time influences the amount of water absorbed by immersed kernels. Kernels of a French domestic wheat, "The Allies," were sorted by slotted sieves into samples of large, medium, and small kernels. Broken kernels were handpicked from the small kernels and they made a fourth sample. All kernels of this variety were equally floury. The absorption of water by each sample during immersion (10 seconds to 6 minutes) was determined through many separate experiments. The samples were centrifuged after immersion. Water absorption was determined by direct weighing or by the drying-oven method. The curves of Nuret's figure 2 show that the amount of water absorbed was in inverse relation to the size of the kernels; the most water was absorbed by the smallest kernels. He attributed this to the fact that the smaller kernels would have a larger absorbing area in relation to weight. The broken kernels absorbed even more water than the small, whole kernels. This probably indicates that breaking the testa had exposed the endosperm, thus permitting rapid penetration by water.

Another experiment of Nuret (466) dealt with the influence of kernel size on water absorption and equilibration in mixtures of domestic (French) and Manitoba wheats. Using the slotted sieve with a hole 2.65 mm. in width, lots of large and small kernels of Manitoba 2, and of large and small kernels of Manitoba 3, were procured. The large kernels of Manitoba 2 and 3 were combined; the small kernels were also combined. Then mixture I composed of large domestic D5 wheat and small Manitoba kernels, and mixture II of large Manitoba kernels and small Manitoba kernels were prepared. The mixtures were immersed for 30 seconds, centrifuged, and held for 24 hours and then, with the same sieve, separated into their components. The final moisture contents were determined by the drying-oven method. Table 109 gives the results. Nuret called attention to the peculiar fact that the percentage of water retained by the small Manitoba wheat kernels was different in the two mixtures. He did not attempt to explain this occurrence.

Effect of kernel size on the rate and the amount of water absorption by equally vitreous large and small kernels of Marquis wheat was investigated by Fraser and Haley (201). Their results, which are similar to those of Nuret, follow:

Kernel size:	Weight gained when immersed for: 0.5 minute	1 minute	5 minutes	30 minutes	60 minutes	Crude protein	Moisture
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Percent*	*Percent*
Large (365/10 g.)	0.43	0.49	0.77	1.19	1.51	13.68	10.3
Small (500/10 g.)	.51	.56	.84	1.37	1.71	13.92	10.2

Investigations of Hinton (305) showed that neither grade of wheat, size of kernel, thickness of skin, nor weathering (repeated wetting near harvest time) had any effect on the rate of movement of water through the testa (seed coat).

Kernel texture

Because of the widespread idea that soft wheats absorb water more quickly than do hard wheats, numerous investigations have been made of the rate of absorption of water by different classes of wheat. Herd (304) compared the absorption of water by different types of wheat at 66° F. Table 110 shows the water absorbed in 30 seconds of immersion by samples of dry wheats and by samples of wheat dampened with 1, 3, and 5 percent water, respectively, and held for 24 hours. The soft wheats listed first in table 110 showed less absorption than did the hard wheats. Many of the wheats showed a slightly lower pickup of water after they had been damped although, in general, damping restricted the pickup very little.

Herd (304) confirmed the slower rate of absorption of water by soft wheats in comparison with hard wheats through tests made in commercial mills. Determinations, in actual percentages of moisture in the samples, were (304, p. 715, table 4):

Washing plant:	Moisture absorption by-- Hard wheat (mixed Manitobas)	Soft wheat (100% Roumanian)	(70% Roumanian, 30% Australian)
No. 1 (Mill B):	*Percent*	*Percent*	*Percent*
Feed to washer	14.0	14.5	13.7
Discharge from whizzer	19.4	17.6	16.8
Gain	5.4	3.1	3.1
No. 2 (Mill B):			
Feed to washer	14.0	14.5	13.7
Discharge from whizzer	18.4	17.2	17.0
Gain	4.4	2.7	3.3
No. 3 (Mill A):			
Feed to washer	13.4	14.4	---
Discharge from whizzer	18.2	17.6	---
Gain	4.8	3.2	---

In addition, Herd gave the gains in moisture content on the washer-whizzer plant in mills which conditioned hard and soft wheats separately. At Mill A the hard wheats gains in moisture content over a long period averaged 5.1 percent and the soft wheats, 3.3 percent; whereas at Mill B the gains averaged 5.5 and 3.9 percent, respectively. Herd made no reference to the size of the kernels of the various soft and hard wheats used in his experiments although he was acquainted with Nuret's work.

Using the same general experimental procedure as Swanson and Pence (see p. 88), Fraser and Haley (201) studied the effect of variety and the time and temperature of immersion on the rate of water absorption (table 111). Turkey variety wheat showed consistently greater absorption than Marquis variety. They stated that the soft Red Russian wheat absorbed less water than almost any other variety. Not all of the figures agree with the statement.

TABLE 109.--*Effect of kernel size on moisture absorption and equilibration in mixtures of wheat*

Wheat types and kernel sizes	Initial moisture content	Mixture I		Mixture II	
		Moisture content, washed wheat	Retained water	Moisture content, washed wheat	Retained water
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Larger[1] domestic wheat-------	14.40	16.30	1.90	---	---
Smaller Manitoba-------------	12.45	16.14	3.69	17.11	4.66
Larger[1] Manitoba-------------	12.45	---	---	16.76	4.31
Difference----------------	---	.16	1.79	.35	.35

[1] Note: The "large D5" was much larger than the "large Manitoba" throughout the trial.

Source: Nuret (466, p. 195).

TABLE 110.--*Water absorbed per 100 grams of wheat during 30 seconds of immersion at 66° F.*

Wheat	Dry	After preliminary damping to--		
		1 percent	3 percent	5 percent
	Grams	*Grams*	*Grams*	*Grams*
English-------	2.8	3.2	2.8	2.5
Australian----	3.4	3.1	3.0	3.4
Danubian------	3.5	3.5	2.9	3.4
Plate---------	3.8	4.0	4.0	3.9
No. 1 Manitoba	4.2	4.0	4.3	4.0
No. 4 Manitoba	4.5	3.9	3.6	4.0
Persian-------	4.3	4.2	3.7	4.0
No. 5 Manitoba	5.1	4.6	4.5	4.1
Latvian-------	5.5	4.5	3.6	3.5

Source: Herd (304, p. 714, table 2).

In another experiment Fraser and Haley (201) tempered 500-gram lots of wheat by the addition of 25 grams of water. Test weights of the varieties varied from 58.6 to 59.6. The tempered lots were held for various lengths of time in closed containers. One-hundred-gram portions were milled by grinding once through a Hobart laboratory mill and then were immediately separated into approximately equal portions of bran, middlings, and flour. The moisture determinations of control and tempered samples are given in table 112.

Farrell (189) used an electric moisture meter to test the rate of moisture equalization in wheats tempered to different moisture levels. A white, a soft red winter, and two different crops of a hard red winter wheat were cleaned in a small separator and run through an experimental scourer. Samples of 1,000 grams each were placed in 1-gallon bottles and a calculated amount of water at 104° F. was added to bring the wheat to the desired moisture level. After water and wheat were thoroughly mixed the bottles were stoppered. Moisture values, obtained with a moisture meter, are given in table 113.

Farrell concluded that in all the wheats tested, except the 1933 crop of hard red winter wheat, absorption was more complete after 8 hours in the samples tempered to the higher than to the lower percentage of moisture. It is apparent from data given in table 113 that approximate equilibration of moisture was reached sooner in the soft wheats, especially the white wheat, than in the hard wheats.

Jones (342) found that Manitoba 1 wheat absorbed about 1.3 times as much water as did a soft French wheat in all periods of immersion from 2 to 60 minutes at 60° F. After 3 hours of immersion the Manitoba wheat had a moisture content of approximately 18 percent and the French wheat, 13 percent. The weight of 100 kernels was 2.87 grams for the Manitoba wheat; 4.71 grams for the French wheat.

TABLE 111. --*The effect of variety, length of time immersed, and temperature of immersion water on the rate and amount of absorption*

Variety	Temperature of water	Weight gained when immersed for--					Crude protein	Moisture
		1/2 minute	1 minute	5 minutes	30 minutes	60 minutes		
	°F.	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Percent*	*Percent*
Marquis--------	56	0.35	0.44	0.67	0.97	1.25		
Marquis--------	103	.48	.56	.76	1.42	1.80	14.5	10.1
Turkey---------	59	.45	.47	.65	1.10	1.49		
Turkey---------	100	.55	.57	.87	1.45	1.95	13.0	10.3
Baart----------	54	.39	.49	.67	.95	1.42		
Baart----------	100	.47	.58	.87	1.28	1.65	13.8	9.9
Hard Federation	56	.35	.42	.63	.96	1.23		
Hard Federation	100	.42	.51	.82	1.36	1.89	10.9	11.3
Club-----------	61	.36	.45	.61	.90	1.21		
Club-----------	102	.43	.53	.76	1.26	1.83	9.5	10.7
Red Russian----	57	.28	.38	.63	1.00	1.33		
Red Russian----	100	.49	.52	.75	1.39	1.62	8.5	11.7

Source: Fraser and Haley (201, p. 46, table 1).

TABLE 112. --*Effect of variety, time, and temperature on the rate of absorption*

Variety and product	Moisture in wheat and products					Crude protein	Temperature of		
	Wheat not tempered	Wheat tempered for--					Room	Wheat	Water
		1 hour	2 hours	3 hours	4 hours				
Baart:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*°F.*	*°F.*	*°F.*
Wheat--------------	9.8	13.6	13.4	13.8	13.8	10.3	75	74	60
Bran---------------	9.4	13.3	13.3	13.5	13.9				
Middlings----------	9.8	13.1	13.1	12.8	13.7				
Flour--------------	10.1	13.2	12.9	12.9	13.6				
Turkey:									
Wheat--------------	9.1	13.2	13.4	13.8	13.7	15.8	74	73	60
Bran---------------	8.5	13.4	13.4	13.9	13.4				
Middlings----------	9.1	12.7	12.7	12.8	13.1				
Flour--------------	9.3	12.7	12.9	12.8	13.2				
Hard Federation:									
Wheat--------------	10.8	13.7	14.3	14.6	15.4	11.9	74	85	60
Bran---------------	10.4	13.6	14.1	14.5	15.8				
Middlings----------	10.5	13.1	13.3	13.7	14.9				
Flour--------------	10.7	13.1	13.2	13.5	14.7				
Wheat--------------	10.7	13.4	13.6	13.9	14.8	11.9	44	45	49
Bran---------------	10.3	13.7	13.8	13.9	14.9				
Middlings----------	10.5	12.5	12.8	13.1	14.2				
Flour--------------	10.5	12.6	13.0	13.4	14.1				

Source: Fraser and Haley (201, p. 48, table V).

TABLE 113. --*Effect of tempering moisture and wheat variety on rate of moisture equalization as shown by electric moisture meter readings*

Wheat and sample no.	Tempered to	Moisture content after tempering for--								
		0.5 hour	1 hour	1.5 hours	2 hours	3 hours	4 hours	5 hours	6 hours	8 hours
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
White wheat:										
1	12	16.7	14.5	13.8	13.3	12.7	12.6	12.6	12.5	12.5
2	12	16.6	14.5	13.8	13.3	12.7	12.6	12.6	12.5	12.5
3	13	18.7	17.3	16.1	14.7	13.8	13.6	13.6	13.4	13.3
4	13	19.4	17.4	16.2	14.6	13.7	13.6	13.6	13.5	13.4
5	14	21.1	19.0	17.1	15.9	14.9	14.6	14.5	14.4	14.2
6	14	21.1	19.1	17.2	15.9	14.9	14.6	14.5	14.4	14.2
7	15	22.6	21.9	19.1	17.2	16.1	15.6	15.3	15.3	15.1
8	15	22.6	22.7	18.9	17.4	16.1	15.6	15.4	15.3	15.1
Hard red winter (1933 Crop):										
9	13	20.0	18.8	17.7	16.1	14.9	14.3	14.2	13.9	13.8
10	13	20.5	19.1	17.4	16.3	14.9	14.3	14.1	13.8	13.7
11	14	21.2	20.3	18.7	17.5	16.1	15.4	15.2	14.8	14.9
12	14	22.1	20.8	18.9	17.6	16.2	15.4	15.1	14.9	14.9
13	15	[1] 24.0	23.9	20.8	19.3	17.4	16.5	16.3	16.2	15.8
14	15	[1] 24.0	23.1	20.9	19.2	17.3	16.5	16.3	16.2	15.8
15	16	[1] 24.0	24.0	22.7	20.3	18.5	17.7	17.3	17.2	17.0
16	16	[1] 24.0	[1] 24.0	23.3	20.3	18.5	17.7	17.5	17.2	17.0
17	17	[1] 24.0	[1] 24.0	[1] 24.0	22.5	19.6	18.7	18.3	18.1	17.9
18	17	[1] 24.0	[1] 24.0	[1] 24.0	21.9	19.8	18.5	18.3	18.0	17.9

		1 hour	1.5 hours	2 hours	2.5 hours	3 hours	4.5 hours	5 hours	6 hours	7 hours	8 hours	9 hours
Hard red winter (1934 Crop):		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
24	13	18.3	16.1	15.3	14.8	14.5	13.9	13.7	13.5	13.5	13.4	13.4
25	14	20.3	18.0	16.7	15.9	15.7	14.9	14.6	14.5	14.4	14.4	14.4
26	15	[2] 24.1	20.4	18.6	17.6	17.2	16.0	15.7	15.6	15.4	15.4	15.3
27	16	[1] 24.0	22.4	19.9	18.9	18.3	17.1	16.8	16.6	16.5	16.4	16.3
28	17	[1] 24.0	24.0	22.0	20.3	19.6	18.2	17.9	17.7	17.4	17.3	17.2
Soft red winter:												
19	13	20.4	17.6	16.5	15.6	15.1	14.3	14.1	14.0	13.9	13.8	13.8
20	14	22.8	20.5	18.6	17.3	16.4	15.4	15.2	15.0	14.8	14.7	14.7
21	15	[1] 24.0	22.5	20.1	18.8	17.9	16.6	16.1	15.9	15.7	15.6	15.6
22	16	[1] 24.0	[1] 24.0	21.6	19.8	18.8	17.5	17.1	16.8	16.6	16.4	16.3
23	17	[1] 24.0	[1] 24.0	22.8	21.2	20.3	18.6	18.2	17.9	17.6	17.5	17.4

[1] The meter did not record higher than 24 percent moisture.
[2] Sic.

Source: Farrell (189, tables 2-5).

Nuret (466) concluded from his experiments that Manitoba wheat absorbed water more eagerly than domestic wheat which had kernels of the same size. He thought that this might be related to the lower initial moisture content of Manitoba wheat. Results of one experiment in which wheats of similar hectoliter weight and kernel shape were treated comparably, were as follows:

Wheat:	Initial moisture	Final moisture	Increase
	Percent	*Percent*	*Percent*
Manitoba, 84 kg./hectoliter	12.51	17.41	4.90
French wheat L4 82 kg./hectoliter..........	13.78	17.23	3.45

Results of another experiment were presented as a graph and showed that domestic wheat whose kernels were between 2.40 and 2.65 mm. in width absorbed moisture to about 21 percent in 6 minutes, whereas Manitoba wheat with larger kernels (only 50 percent were less than 2.65 mm. in width) had reached only about 19-percent moisture content. Nuret assumed that the Manitoba wheat would have absorbed more water than the French wheat if the kernels of both had been of equal size.

The work of Schäfer (551) indicates that the difference in rate of water absorption between hard and soft wheats or between the endosperm alone of hard and soft wheats depends on time of exposure to moisture. Schäfer's figure 5 is a graph which shows curves for the average water absorption of 10 foreign wheats and of 40 German domestic wheats during 10-minute immersion. Each wheat sample was freed of excess water by rolling it between blotters or by centrifuging, and moisture content was determined by a 2-stage oven method. The foreign wheats were, in general, harder and more glassy than the domestic wheats.

During the first 2 minutes of immersion foreign wheats absorbed about 1 percent more water than did domestic wheats. The rate of absorption of the foreign wheats then gradually decreased and after 10 minutes foreign wheats contained only about 0.5 percent more water than did the domestic wheats.

The difference in water absorption between the endosperm of hard and of soft wheat was shown in figure 6 (551) in which the area (in square millimeters) that stained blue with iodine was plotted against time. Entrance of water into the endosperm of soft wheat kernels began after 1 hour of immersion; entrance into the endosperm of hard wheat, after 3 hours. Although the endosperm of hard wheat absorbed water more slowly in the period from 3 to 5 hours, the rate of absorption increased tremendously between 5 and 6 hours, so that after 6 hours the area that would stain with iodine nearly equalled that found in the endosperm of soft wheat kernels.

Nuret (466) investigated water absorption by handpicked mealy and vitreous kernels from a lot of French domestic wheat L4 that had been carefully graded as to size. Vitreous kernels absorbed more water than did mealy kernels. The vitreous kernels were, however, more wrinkled and had a greater cavity in their ventral fold. When a similar experiment was made with a wheat in which the mealy kernels had the aforementioned characteristics, the mealy kernels absorbed more water than did the vitreous kernels. Nuret concluded that the effect of mealiness or vitreousness of the kernel on water absorption was slight.

Water absorption by the endosperm in vitreous and mealy kernels of hard and soft wheats was studied by Hinton (305) (table 114). A capillary tube containing water was held against the exposed endosperm and the rate of absorption was measured by the rate of movement of the water meniscus in the tube. Mealy kernels of "Holdfast (2)" were more mealy than those of "Holdfast (1)." The difference in water absorption between vitreous and mealy samples of each variety was statistically significant. Mealy endosperms were more permeable, the degree of permeability depending on the degree of mealiness. Permeability was not affected by the class of wheat (hard or soft).

Mambish and Demidov (413) investigated the rate of penetration of moisture in sam-

TABLE 114.--*Comparison of the rate of movement of water through the endosperm of vitreous and mealy kernels of hard and soft wheats ($\mu l./sq. cm./hour$)*

Class and variety of wheat	Vitreous kernels	Mealy kernels
Hard:		
Atle----------------	20.2	26.8
Holdfast (1)--------	20.5	26.4
Holdfast (2)--------	---	37.5
Soft:		
Bersée--------------	21.3	26.4
Koga----------------	20.2	36.7

Source: Hinton (305, p. 301, table II).

TABLE 115.--*Rate of entrance of moisture into kernels of "Novoukrainka" wheat samples of different vitreousness during moist storage at an air temperature of 15°-20° C.*

Duration of moist storage, hour(s)	Moisture in samples of wheat kernels having a general vitreousness of --		
	77 percent	60 percent	40 percent
	Determined by electric moisture meter		
	Percent	*Percent*	*Percent*
0--------------	23.40	23.40	23.40
.5-------------	21.00	20.30	20.30
1.0------------	19.40	18.80	18.80
1.5------------	18.50	17.85	17.95
2.0------------	17.90	17.30	17.30
2.5------------	17.35	16.90	16.70
3.0------------	16.85	16.50	16.10
3.5------------	16.50	16.10	15.80
4.0------------	16.20	15.70	15.40
4.5------------	15.95	15.50	15.30
5.0------------	15.65	15.40	15.20
5.5------------	15.50	15.30	15.00
6.0------------	15.50	15.15	15.00
6.5------------	15.35	15.00	15.00
7.0------------	15.25	15.00	15.00
7.5------------	15.20	15.00	15.00
8.0------------	15.15	15.00	15.00
8.5------------	15.15	15.00	15.00
9.0------------	15.10	14.88	15.00
9.5------------	15.10	14.88	---
10.0-----------	15.10	---	---
	Determined by drying method		
0--------------	15.22	15.20	15.20
10-------------	15.10	15.02	14.98

Source: Mambish and Demidov (413, p. 20, table 13).

ples of "Novoukrainka" wheat that differed in percentage of vitreous kernels. Table 115 shows the approach to equilibrium as indicated by electric moisture meter readings. The sample with only 40 percent vitreous kernels reached equilibrium in 5.5 hours, whereas the sample with 77-percent vitreous kernels required 9 hours to reach equilibrium.

Summary

The consensus concerning the place of entrance of water into the wheat kernel was that at room temperature water entered immersed kernels first and most abundantly through the germ end and only much later through other portions; at higher temperatures (70° to 100° C.) and in steam under pressure, the selective penetration at the germ end was minimized. It was recognized that breaks in the outer layers of the kernel and the presence of fracture lines in the endosperm affected the pattern of water absorption. The barrier layer limiting absorption of moisture through the bran was reported to be the testa (seedcoat).

The rapid initial pickup of 4 to 5 percent water by immersed kernels was found to be unaffected by temperature, but the rate of absorption after about 2 minutes was greatly increased by an increase in the temperature of the water. A greater and a slightly more rapid absorption of water by small than by large kernels (assuming samples of equal weight and kernels of similar texture) was reported (201, 466) and attributed to the larger absorbing surface of the small kernels.

Data on the effect of kernel class and texture on water absorption were somewhat conflicting. It was claimed that soft wheats absorbed less water than did hard wheats (201, 304) and that moisture equilibration was reached sooner in soft wheats (189). Other reports stated that within a variety vitreous kernels (413) and vitreous endosperm (305) absorbed water more slowly than did mealy kernels or endosperm. It was suggested that a lower initial moisture content, not different texture, was responsible for greater absorption of water by Manitoba wheat kernels than by kernels of French domestic wheat of equal size (466).

Variations with time in the rate of water absorption by hard and by soft wheats were pointed out (551). The failure to take into account these variations and other factors such as kernel size may account for some of the seeming contradictions in conclusions.

PART III.--BIBLIOGRAPHY

References are arranged alphabetically by authors and numbered consecutively. References marked with an asterisk have not been seen by the authors. Identical or closely similar articles that were published in different periodicals have been grouped in one citation and given only one number. The article in the first journal named is the one reviewed. The others may or may not have been verified directly; some were verified only through other references. Some references in Russian or Hungarian were obtained but were not translated because of lack of facilities. These are marked with a dagger. For the convenience of the reader, all titles in foreign languages are preceded by an English translation.

Anonymous. 1

Carrier-Miller Wheat Conditioning Apparatus. In Ideal Wheat Conditioning Brought From Realm of Theory to Your Roll Floor. Amer. Miller 55(2): 173 (Feb. 1, 1927).

—————— 2*

Wheat Conditioning. Milling (Liverpool) 73(10): 400 (1929). [Through 408.]

—————— 3

[Improvement of Baking Quality of Flour Through Physical Means.] Verbesserung der Backfähigkeit des Mehles mittels physikalischer Mittel. Mühle 68(2): 35-36 (1931).

—————— 4

[Wheat Conditioning. Determination of the Degree of Conditioning With Tempering Bins.] Weizen-Konditionierung. Feststellung der Intensität der Konditionierung mit Abstehbehältern. Mühle 69(22): 557-558 (June 2, 1932).

—————— 5

Discussion of Tempering. In Questions and Answers. Northwest. Miller 185: 192 (Jan. 15, 1936).

—————— 6

Apparatus Wheat Conditioning. [A comparison of European and North American Methods.] Northwest. Miller 192(1): 37-38, 42 (Oct. 13, 1937).

—————— 7

[The Effect of Heat on the Gluten Quality and Baking Capacity of Wheat. The Results of a Conference at the Institute for Milling.] Die Einwirkung der Wärme auf Kleberbeschaffenheit und Backfähigkeit des Weizens. Die Ergebnisse der Diskussionstagung im Institut für Müllerei. Mehl u. Brot 38(23): 1-3 (June 10, 1938).

—————— 8

The "how and why" of American Milling Equipment. Part 6. Preparatory Procedure. Amer. Miller 75(8): 32,34,82,85 (Aug. 1947).

—————— 9

Apparatus Wheat Conditioning. Amer. Miller 75(12): 55-59, 84-86, 89,91 (Dec. 1947).

—————— 10

German Wheat Conditioner Uses Vacuum Principle for Rapid Water Penetration. Northwest. Miller 239(11), Sect. 2: 16a (Sept. 13, 1949).

—————— 11

[Moisture Control in Small Mills.] Die Feuchtigkeitskontrolle in Kleinmühlen. Deut. Müller-Ztg. 49(16): 408-409, 417 (Aug. 8, 1951).

—————— 12

[II. The Conditioning of Grain.] II. Die Vorbereitung des Getreides. In Fachkunde für Müller, pp. 69-76. [Enclosed in Mühle 91(19): (May 13, 1954).]

—————— 13

[Moisture Transfer From Damp to Dry Wheat During Storage.] Feuchtigkeitsübertragung von feuchtem auf trockenen Weizen bei der Lagerung. Mühle 91(34): 425 (Aug. 26, 1954).

—————— 14

[Cold Treatment.] Kältebehandlung. Mühle 92(44): 591 (Nov. 3, 1955).

—————— 15

[Water Absorption by Dried Grain.] Wasseraufnahme von getrocknetem Getreide. Mühle 92(48): 647-648 (Dec. 1, 1955).

Anonymous. 16

[Conditioning of Cereal Grains with Infrared Rays.] Condizionamento di cereali mediante raggi infrarossi. Selezione di Tech. Molitoria 7(4): 94 (April 1956). [From Elektro-Waerme-Technik (Germany) No. 5/6: 101-103 (1955).]

——— 17

The Objects of Conditioning. In Flour Milling Correspondence Course. Milling (Liverpool) 124(9): 268,270 (Feb. 26, 1955); 128: 306,308 (Mar. 9, 1957).

——— 18

[Conditioning With Radiant Heat for Milling.] Vermahlungskonditionierung mit Strahlungswärme. Mühle 95(29): 382-383; (30): 398-399 (July 17, 24, 1958).

Alroth, K. Friedr. 19

[The Improvement of Flour Quality by Mechanical Means.] Die Verbesserung der Mehlqualität auf mechanischem Wege. Mühle 66 (23): 695-698 (June 6, 1929).

Alroth, Fr. 20

[Conditioning of Grain in Small and Medium-sized Mills.] Die Vorbereitung des Getreides in Klein- und Mittelmühlen. Mühle 72(33): 1,047-1,048 (Aug. 16, 1935).

Altrogge, Ludwig. 21

[New Experiments on the Conditioning of Rye.] Neue Erfahrungen zur Roggen-Konditionierung. [In 421, pp. 54-58.] From Getreide, Mehl u. Brot 4(17/18): 189-192 (Sept. 1950).

——— 22

[Some Experiments and Some Trends Relative to the Development of the Conditioning of Cereal Grains.] Des experiences et des tendances concernant le développement du conditionnement des céréales. Meun. Franç. No. 51: 38-44 (Oct. 1950). [Also in Cong. Internatl. des Indus. Agr. Rap. 8(1): 540-541 (1950).]

——— 23

[Further Development of Cereal Grain Conditioning.] Zur Weiterentwicklung der Getreidekonditionierung. Mühle 88(4): 49-50 (Jan. 25, 1951).

——— 24

[New Findings in Wheat Conditioning with the Steam-Addition Method.] Neue Ergebnisse in der Weizenvorbereitung mit dem Dampfzusatzverfahren. In Wissenschaftlich-technisches Kolloquium von Arbeitsgemeinschaft Getreideforschung e.V., Detmold, vom 24 bis 26. Oktober 1955. Mühle 92(44): 589-590 (Nov. 3, 1955).

——— 25

[Experiments With the Netzolit Method.] Versuche mit dem Netzolit-Verfahren. Ibid., 590.

——— 26

[The Humidol Method.] Das Humidol-Verfahren. Ibid., 590-591.

——— 27

[New Results in Steam Conditioning.] Neues zur Dampfkonditionierung. Mühle 94(43): 558-559 (Oct. 24, 1957).

——— and Schäfer, W. 28

[Steam Treatment of Uninjured Wheat.] Die Dampfbehandlung von unbeschädigtem Weizen. In their Präparation von Auswuchsgetreide zur Verbesserung der Backfähigkeit. Mühle 91(43): 562-566 (Oct. 28, 1954).

American Association of Cereal Chemists. 29

Cereal Laboratory Methods. Ed. 6, edited by Emery C. Swanson. St. Paul, Minn. (1957).

Amos, A. J. 30

Flour Milling. In F. Aylward, Food Technology, Processing and Laboratory Control, pp. 71-94. Newnes, London (1955).

Amos, P. A. 31

Wheat Drying and Conditioning. In his Processes of Flour Manufacture. Ed. 3, revised by Jas. Grant, pp. 118-129. Longmans, Green, London (1925).

Anders, E. 32

[The Present Status of Grain Conditioning.] Der gegenwärtige Stand der Getreidevorbereitung. [Includes review of literature.] Jahrb. der Müllerei 58: 33-44 (1954).

Anders, E. 33
[Distribution of Moisture in Grain for Milling.] Die Feuchtigkeitsverteilung im Mahlgetreide. Jahrb. der Müllerei 59: 148-150 (1955).

——— 34
[Research on the Improvement of the Gluten Quality of Wheat Through Ultrasonic and Infrared Rays.] Versuche zur Verbesserung der Kleberqualität von Weizen durch Ultraschall und Infrarotstrahlen. Inst. f. Ernährforsch. Potsdam. Ernährforsch. 1: 379-385 (1956).

Anderson, J. E. 35
What Water Does to Wheat in Tempering. Assoc. Oper. Millers Bul., pp. 794-797 (May 1937).

——— 36
Equilibrium Relative Humidities for Hard Wheat and Mill Stocks. Northwest. Miller 192(1): 20-22 (Oct. 13, 1957).

——— 37
It Doesn't Sound Reasonable--Cooling Wet Wheat With Warm Air--but Here's how it Works. Northwest. Miller 217(2), Sect. 2: 13a, 19a (Jan. 12, 1944).

Annen, Hermann. 38
[The Present Status of Grain Conditioning.] Der heutige Stand der Konditionierung. Mühle 72(33): 1,031-1,034 (1935).

Argus. 39
[Grain Conditioning. Previous Successes, Failures, and Thoughts About the Future.] Die Getreidevorbereitung. Seitherige Erfolge, Misserfolge und Zukunftsgedanken. Mühle 75(22): 599-600 (June 3, 1938).

Association of Operative Millers. 40
Technical Bulletins of Association of Operative Millers. V. 1, 1920 to 1937; v. 2, 1937 to 1943. Sosland Press, Kansas City, Mo. (May 15, 1948).

——— 41
Wheat Conditioning. Short Time Conditioning. In Milling Practice 1 and 2. Correspondence Course in Flour Milling, Lessons 11 and 12, Unit II. Kansas State College, Manhattan (1950).

Association of Operative Millers Technical Committee. 42
Preliminary Survey on Wheat Conditioning. Assoc. Oper. Millers Bul., pp. 2,295-2,296 (Dec. 1956). [Abstract in Northwest. Miller 255(19): 11 (May 8, 1956).]

Atkinson, F. M. 43
Major Wheat Conditioning Problems: Current World Practices, Opinions. Northwest. Miller 258(15): 14-15, 18-19, 32 (Oct. 8, 1957). [Excerpt in Amer. Miller 85(11): 28 (Nov. 1957).]

Auer, C., and Ritter, K. 44
[Improvement of Baking Quality Through Infrared Radiation.] Verbesserung der Backfähigkeit durch Infrarotstrahlung. German Patent 899,632. (Abstract.) Mühle 90(53): 803 (Dec. 31, 1953).

Auer, Ernst. 45
Spring Wheat Conditioning. Illustrated Abstract of the Author's Report Before AOM District 8 at Buffalo Last Month. Amer. Miller 85(3): 22-23 (Mar. 1957).

——— 46
European Milling Developments. Northwest. Miller 257(13): 13 (Mar. 26, 1957).

B. 47
[How Shall I Condition Wheat?] Wie konditioniere ich den Weizen? Mühle 66(1): 9 (1929).

B, G. (Holland). 48
[Grain dampening.] Getreide netzen. Mühle 70(29): 741 (1933).

B, H. von (Belgium). 49
[Conditioning Without a Conditioner.] Weizenvorbereitung ohne Vorbereiter. Mühle 69(2): 31-32 (1932).

B., M. 50
[Conditioning of Grain and the Column Drier.] Vorbereiten des Getreides und Schachttrockner. Mühle 70(14): 343 (1933).

B., V. (Holland). 51
[Contribution to Conditioning.] Beitrag über das Konditionieren. Mühle 67(6): 149-150 (Feb. 6, 1930).

Babbitt, J. D. 52
Hysteresis in the Adsorption of Water Vapor by Wheat. Nature 156(3957): 265-266 (Sept. 1, 1945). [Reprinted in Milling (Liverpool) 105: 192 (Sept. 15, 1945).]

———— 53
The Thermal Properties of Wheat in Bulk. Canad. Jour. Res., Sect. F, Technol. 23(6): 388-401 (Nov. 1945).

———— 54
Observations on the Adsorption of Water Vapor by Wheat. Canad. Jour. Res., Sect. F, Technol. 27(2): 55-72 (Feb. 1949).

Bailey, C. H. 55
The Relation of Certain Physical Characteristics of the Wheat Kernel to Milling Quality. Jour. Agr. Sci. 7: 432-442 (1916).

———— 56
The Chemistry of Wheat Flour. 324 pp. Chemical Catalogue Co., New York (1925).

———— 57
Science and Practice in Wheat Tempering. Factors to be Considered in Tempering Procedure and the Relation of These Factors to Each Other. Amer. Miller 55(1): 55 (Jan. 1, 1927). [Also in Natl. Miller 32(1): 25 (1927).]

Barker, R. H. 58*
What the Miller Should Know. Amer. Miller 63(3): 20 (1935). [Through 406.]

Bauer, E. T. 59
Proper Conditioning and Tempering of Wheat. Oper. Miller 20: 381-383 (1915).

Bayles, B. B. 60
Determining Utility Values of Wheat Varieties. Northwest. Miller 239(6), Sect. 2: 6a-8a (Aug. 9, 1949). [Also in Milling Prod. 14: 10-12 (Aug. 1949).]

Becker, Fritz. 61
[Wheat Conditioning.] Weizenkonditionierung. Mühle 75(3): 55-56 (Jan. 21, 1938).

Becker, H. A., and Sallans, H. R. 62
A Study of Internal Moisture Movement in the Drying of the Wheat Kernel. Cereal Chem. 32(3): 212-226 (May 1955).

———— and Sallans, H. R. 63
A Study of the Desorption Isotherms of Wheat at 25° C. and 50° C. Cereal Chem. 33(2): 79-91 (Mar. 1956).

———— and Sallans, H. R. 64
A Study of the Relation Between Time, Temperature, Moisture Content, and Loaf Volume by the Bromate Formula in the Heat Treatment of Wheat and Flour. Cereal Chem. 33(4): 254-265 (July 1956).

———— and Sallans, H. R. 65
A Theoretical Study of the Mechanism of Moisture Diffusion in Wheat. Cereal Chem. 34(6): 395-409 (Nov. 1957).

Berliner, Ernst. 66
[What Takes Place in the Wheat Kernel During Conditioning?] Was geschieht im Weizenkorn während der Vorbereitung? Mühle 70(45): 1,163-1,166 (Nov. 9, 1933).

Berliner, Ernst. 67

[Improving the Baking Quality of German Wheat by Conditioning.] Über die Backverbesserung deutschen Weizens durch den Vorbereiter. Mühlenlaboratorium 5(6): 81 (June 1935).

——— 68

[Concerning Conditioning of Hard and Soft Wheats and its Control. A Review and a Forecast.] Über Hart- und Weichweizenvorbereitung und ihre Kontrolle. Ein Rück- und Ausblick. Mühle 72(33): 1,033-1,036 (1935).

——— 69

[On Gluten Quality and Gluten Degradation by Proteases of the Wheat Kernel.] Über Kleberqualität und Kleberabbau durch die Proteasen des Weizenkornes. Mühlenlaboratorium 7(4): 57-62 (1937).

——— 70

[Relation Between Temperature and Time in Wheat Conditioning.] Über die Zusammenhänge zwischen Temperatur und Zeit bei der Weizenkonditionierung. Mühlenlaboratorium 7(12): 175-178 (1937).

——— 71

[Investigation of the Effect of Conditioning on the Inner Properties of the Wheat Kernel.] Untersuchungen über die Wirkung der Vorbereitung auf die inneren Eigenschaften des Weizenkorns. Mühle 75(22): 605-608 (June 3, 1938).

——— 72

[Concerning the Relationship Between Tempering Wheats for Milling and for Baking.] Über die Zusammenhänge zwischen mahl- und backtechnischer Vorbereitung des Weizens. Mühle 88(4): 45-46 (Jan. 25, 1951).

——— 73

[The Influence of Wheat Conditioning and Chemical Treatment of Flour on the Baking Qualities.] Der Einfluss der Weizenvorbereitung und chemischen Mehlbehandlung auf die Backfähigkeit. [Abstract] in Diskussionstagung des Forschungsinstituts für Getreidechemie. Deut. Müller-Ztg. 49(5): 121-122 (Mar. 7, 1951). [Also in Zweite Jugenheimer Diskussionstagung. Mühle 88(9): 138-139 (Mar. 1, 1951).]

——— 74

[Effect of Storing, Conditioning and Chemical Treatment of Flour on the Baking Quality.] Einfluss von Lagerung, Konditionierung und chemischer Mehlbehandlung auf die Backfähigkeit. [Abstract in Diskussionstagung des Forschungsinstituts für Getreidechemie. Deut. Müller-Ztg. 49(20): 513-514 (Oct. 1951).]

——— 75

[Testing Gluten Quality. The Principle of the Gluten Swelling Test.] Die Kleberqualitätsprüfung. Das Prinzip der Kleberquellprüfung. In his Getreide-Chemie für den praktischen Müller. Deut. Müller-Ztg. 49(22): 559-560; (24): 612-613 (Oct. 31; Nov. 28, 1951).

——— 76

[Relation Between Grain Storage, Hot Conditioning and Chemical Treatment.] Zusammenhänge zwischen Getreidelagerung, Wärmekonditionierung und chemischer Behandlung. [Abstract in Die 3. Jugenheimer Diskussionstagung. Mühle 89(11): 162-163 (Mar. 13, 1952).]

——— 77

[Granulation and Diastatic Power.] Griffigkeit und diastatische Kraft. Deut. Müller-Ztg. 51(5): 107-109 (1953).

——— 78

[Storing, Drying, Holding, and Conditioning and Their Influence on Baking Quality.] Lagerung, Trocknung, Abstehen, und Konditionieren und deren Einfluss auf die Backfähigkeit. [Abstract in 4. Diskussions-Tagung des Forschungsinstituts für Getreidechemie. Deut. Müller-Ztg. 51(7): 150-151 (Apr. 1, 1953).]

Berliner, Ernst. 79
[Grittiness and Smoothness.] Griff und Schliff. Müllerei 6(35): 530-531 (Aug. 29, 1953).

________ 80
[The Relationship Between Nitrogen (Protein) Content and Gluten Content in Wheats and Flours, its Change Through Nitrogen Fertilization on the One Hand and Through Storage, Aging, Conditioning and Chemical Treatment on the Other Hand.] Die Beziehung zwischen Stickstoff- (Protein-) und Klebergehalt in Weizen und Mehlen, ihre Verschiebung durch Stickstoffdüngung einerseits und durch Lagerung, Alterung, Konditionierung und chemische Behandlung andererseits. [Abstract in 5. Jugenheimer Diskussionstagung. Deut. Müller-Ztg. 52: 155 (Mar. 31, 1954); and Mühle 91(14): 171 (Apr. 8, 1954).]

________ 81
[Concerning the Relationship Between Gluten Content and Gluten Strength.] Über die Zusammenhänge Zwischen Klebergehalt und Kleberfestigkeit. Mühle 93(12): 165-167; (13): 181-182 (Mar. 22, 29, 1956).

________ and Kipper, W. 82*
[Use of Infrared Rays for Drying of Washed Grain.] Die Verwendung von infraroten Strahlen zur Trocknung von gewaschenem Getreide. Müllerei 6(14): 199-200 (April 4, 1953). Through Bibliography Agr. 17: 66,971 (1953).

________ and Koopmann, J. 83
[Colloidal Chemical Studies of Wheat Gluten, Including a Description of a New Gluten Test.] Kolloidchemische Studien am Weizenkleber nebst Beschreibung einer neuen Kleberprüfung. Z. ges. Mühlenw. 6(4): 57-63 (July 1929).

________ and Rüter, R. 84
[Flour Microscopy. 3. The Microscopic Structure of the Particles of Wheat Flour and Their Influence on the Millability of Wheat.] Mehlmikroskopie. 3. Die mikroskopische Struktur des Weizenmehlkörpers und ihr Einfluss auf die Vermahlbarkeit des Weizens. Z. ges. Mühlenw. 5(6): 105-108 (Sept. 1928).

Berndt, Helmut. 85
[Moisture Content of Cereal Grains Before the First Break and Water Content of the Flour.] Getreidefeuchtigkeit vor dem ersten Schrot und Wassergehalt des Mehles. Deut. Müller-Ztg. 53: 32 (Jan. 26, 1955).

Bethke, C. A. 86
Conditioning Soft Wheat. Northwest. Miller 207, Sect. 2: 11a (Aug. 13, 1941).

Beuschlein, W. L., and Barkey, K. 87
Temperature--Moisture--Humidity Relations of Wheat. In 40, v. 2., pp. 367-376. [n.d.]

Biekasow, A. G., and Denisow, N. I. 88*
[Grain Research.] Warsaw (1956). [In Russian. Through 340.]

Block, W. 89
[Tempering in the Small Mill.] Das Netzen in der Kleinmühle. Mühle 90(43): 648 (Oct. 22, 1953).

Borg, L. P. 90
[Some Observations About Moisture and Dampening of Grain.] Einige Betrachtungen über die Feuchtigkeit und die Netzung des Getreides. Z. ges. Mühlenw. 5(10): 182-183 (Jan. 1929).

Boulanger. 91
[Does Conditioning Affect Baking Quality and Milling Capacity?] Werden Backfähigkeit und Mahlbarkeit durch Vorbereiten beeinflusst? Mühle 75(22): 603-606 (June 3, 1938).

________ 92
[Conditioning of the Grain of 1938.] Konditionierung des Getreides von 1938. Mühle 76(5): 117-124; (6): 145-150 (Feb. 3, 10, 1939).

Bouskill, Ralph. 93
What are the objects in Wheat Milling? Assoc. Oper. Millers Bul., pp. 2,313-2,314 (April 1957).

Brabender, C. W. 94
[Conditioning or Tempering?] Konditionieren oder abstehen? Mehlprobleme 1: 46-49 (1932).

________ 95
[Contribution on Conditioning of Wheat.] Beitrage zur Weizenkonditionierung. Mühle 70(22): 557-560 (June 1, 1933).

________ 96
[Recent Research into the Effect of Conditioning of Wheat.] Neuerliche Untersuchungen über den Weizenkonditionierungseffekt. Mehlprobleme 4(1): 2-5 (1935).

________ 97
[Wheat Evaluation and Baking Test.] Weizenbewertung und Backversuch. Mehlprobleme 4(1): 6-7 (1935).

________ 98
Development of Tempering and Conditioning in Europe and Utilization of These Experiences in American Milling. Assoc. Oper. Millers Bul., pp. 658-662 (Sept. 1935).

________ 99
"Hot and Cold Conditioning of Wheat." Assoc. Oper. Millers Bul., pp. 910-915 (Sept. 1938). [Also in 40, v. 2, pp. 135-143.]

________ and Abdon, Sten. 100
[The Migration of the Gluten Optimum in the Mill Streams Under the Influence of Changes in Conditioning.] Das Wandern der Kleberoptima in den Mehlpassagen unter dem Einfluss veränderter Konditionierung. Mehlprobleme 3: 15-17 (1934).

________ and Mueller, G. 101
[Is a Standard Conditioning System possible?] Ist eine "Rezept" -mässige Konditionierung möglich? Z. ges. Getreidew. 25(5): 95-100 (1938).

Bradbury, Dorothy, Cull, Irene M., and MacMasters, M. M. 102
Structure of the Mature Wheat Kernel. I. Gross Anatomy and Relationships of Parts. Cereal Chem. 33(6): 329-342 (Nov. 1956).

Braun, H. D. 103
[Cleaning and Tempering of Wheat in Canadian Small Mills.] Reinigen und Vorbereiten des Weizens in Kanadischen Kleinmühlen. Mühle 64(28): (1927).

Briggs, C. H. 104
The Conditioning and Milling of Grain. I. Northwest. Miller 144: 988-989 (Dec. 9, 1925).

________ 105
Tempering and Conditioning Wheat. Northwest. Miller Prod. Ann. Sup. 180(1): 19-20 (Oct. 10, 1934).

________ 106*
Conditioning and Milling of Grain. Northwest. Miller 187(9): 751 (1936). [Through 406.]

Brisach, Carl. 107
[Grain Scouring.] Getreideenthülsung. Mühle 69(4): 81-82 (Jan. 28, 1932).

________ 108
[Wheat Conditioning Without a Washer.] Weizenvorbereitung ohne Wäscherei. Mühle 69(41): 1,067-1,068 (Oct. 13, 1932).

________ 109
[Wheat Conditioning.] Weizenvorbereitung. Mühle 70(5): 106 (Feb. 2, 1933).

Brisach, Carl. 110*
[Conditioning of Scoured Kernels.] Konditionierung des enthülsten Kornes. Mühle 70 (45): 1,188-1,189 (1933).

——— 111
[On Scouring and Conditioning.] Über Enthülsungskonditionierung. Mühle 72(33): 1,043-1,044 (1935).

Brooke, C. L. 112
Recent Progress in Cereal Chemistry. Cereal Chem. 13(4): 367-388 (July 1936).

Brose. 113
[Wheat Conditioning and Drying.] Weizenvorbereitung und -trocknung. Mühle 70(8): 182 (Feb. 23, 1933).

Brückner, G. 114
[Determination of Heat Damage in Grain Drying. Part 1. A Survey of the Problem.] Bestimmung von Hitzeschäden bei der Getreidetrocknung. 1. Mitteilung: Eine Studie zur Problematik. Getreide u. Mehl 7(10): 81-85 (Oct. 1957). [Abstract in Mühle 94 (24): 305 (1957).]

Buré, Jean. 115
[The Passage of Water into the Interior of Grain Kernels During the Course of Conditioning and Drying.] Le cheminement de l'eau à l'intérieur des grains au cours du conditionnement et du séchage. Meun. Franç. No. 39: 26-32 (1949). [Also in Bul. École Meun. Belge 11(5): 85-96 (1949). Abstract in Miller (London) 81: 151 (Feb. 6, 1950); Milling (Liverpool) 113: 192 (Aug. 27, 1949); and Tolva 8: 264-267 (Apr. 1950).]

——— 116
[Thermal Exchanges in Grains.] Les échanges thermiques dans les grains. Meun. Franç. No. 42: 33-36 (Dec. 1949).

——— 117*
[Passage of Water to the Interior of the Kernel.] Le cheminement de l'eau à l'intérieur des grains. In his La Vie des Grains. Compt. rend. journée preparatoire d'étude sur le séchage. Edited by Assoc. Producteurs Blé et Autres Céréales. Paris (1952). Reference and translation through G. M. Grosh.

——— 118
[The Hygrometric State of the Air. Determination. Influence in the Cereal Industries.] L'état hygrométrique de l'air. Détermination. Influence dans les industries des céréales. Tech. Meun. 56: 5-13 (Mar./Apr. 1956).

——— and Cosse, S. 119
[The Movement of Water into the Interior of the Kernel.] Le cheminement de l'eau à l'intérieur des grains. Acad. d'Agr. de France Compt. Rendt. 35(7): 247-248 (1949).

Campbell, J. D. 120
The Effect of Mechanical Damage to Wheat Grains During Scouring on Their Subsequent Absorption of Water During Washing. Cereal Chem. 35(1): 47-56 (Jan. 1958).

——— and Jones, C. R. 121
The Effect of Temperature on the Rate of Penetration of Moisture Within Damped Wheat Grains. Cereal Chem. 32(2): 132-139 (Mar. 1955).

——— and Jones, C. R. 122
On the Physical Basis of the Response of Endosperm Density to Change in Moisture Content. I. Densities of Dissected and of Milled Endosperm Particles. II. Reversibility of Endosperm Density on Drying in Relation to Behavior of Whole-Wheat Grains. Cereal Chem. 32(4): 325-333, 333-343 (July 1955).

——— and Jones, C. R. 123
The Rates of Penetration of Moisture to Different Points in the Central Cross-Section of the Endosperm in Damped Manitoba Wheat Grains. Cereal Chem. 34(2): 110-116 (Mar. 1957). [Abstract in Mühle 94(48): 628-629 (Nov. 28, 1957).]

Chamberlain, Joseph. 124

A Comparison of American and British Milling. Assoc. Oper. Millers Bul., pp. 428-431 (June 1932). [Also in Northwest. Miller 170: 712-714 (June 15, 1932); and Modern Miller, pp. 19-20 (July 2, 1932).]

Charles, Willis. 125

Tempering Soft Wheat for Milling. In Indiana Operatives Meet. Amer. Miller 55(11): 1,194 (Nov. 1, 1927).

———— 126

The Tempering of Wheat. Northwest. Miller 187: 772 (1936).

Christie, E. A. 127

Tempering and Conditioning. Amer. Miller 67(7): 26-30 (July 1939). [Also in Assoc. Oper. Millers Bul., pp. 966-967 (1939); and Northwest. Miller 199, Sect. 2: 11a (July 12, 1939).]

Cleve, Heinz. 128

[Conditioning of Grain by the Use of Vacuum.] Die Konditionierung des Getreides unter Anwendung von Vakuum. [In 421, pp. 63-64.] From Z. ges. Getreidew. 26(4): (1939).

———— 129

[Conditioning.] Konditionierung. [In 421, pp. 61-63.] From Mühle 76(46): (1939).

———— 130

[Survey of Equipment and Methods Available for Conditioning.] Übersicht über heute zur Verfügung stehende Apparate und Verfahren zur Konditionierung. Getreide, Mehl u. Brot. 3(23/24): 252-255 (Dec. 1949).

———— 131

[New Conditioning Processes.] Les nouveaux procédés de conditionnement. Meun. Franç. 96: 25-30 (Nov. 1954). With title "Die neuen Vorbereitungsverfahren," in Bul. École Meun. Belge 14(3): 78-83; (4): 105-112; (5): 145-150; (6): 167-177; 15(1): 23-31 (May/June 1952-Jan./Feb. 1953). [Also in Wiss. Müllerei No. 2: 17-29; No. 3: 37-44. In Müllerei 5: (Feb. 23, Mar. 22, 1952). Condensed in 421, pp. 19-32.]

———— 132

[New Knowledge Concerning the Entrance of Water into the Kernel of Grain.] Neue Erkenntnisse über die Eindringung des Wassers in das Getreidekorn. In 421, pp. 52-54.

———— 133

Outer-Layer Treatment of the Grain. Miag-News, second issue, English edition, pp. 23-27. Miag, Braunschweig (1953).

———— 134

Conditioning of Wheat. The Outer-Layer Process. [Translated from Mühle 91(33): 413-414; (34): 426-427 (Aug. 19, 26, 1954).] In Milling (Liverpool) 123: 478-479; 540,542,559 (Oct. 23, Nov. 6, 1954).]

———— 135

[The Treatment of Wheat by the Procedure Using Addition of Steam.] Le traitement des blés par le procédé d'adjonction de vapeur. Bul. École Meun. Belge 17(4): 65-70 and colored plate (1955). With title "Das Dampfzusatzverfahren" in Miag Nachrichten 95,553, pp. 8-12. Miag, Braunschweig. [Also in Selezione di Tec. Molitoria 7(6): 43-47 (June 1956).]

———— 136

[Improved Conditioning by Controlling the Effect of Conditioning. Parts I and II.] Besseres Konditionieren durch Kontrolle des Konditioniereffektes. I. Teil, II. Teil. Müllerei 10(29): 393-394; (30): 407-409 (July 20, 27, 1957).

———— 137

[Wheat Conditioning.] Weizenkonditionierung. Allg. Mühlen-Markt 58(854): 243-246; (855): 262-264 (Aug. 20, Sept. 5, 1957).

Cleve, Heinz. 138

[Milling Problems Which Arise With the Prohibition of Chemical Additives.] Müllerische Probleme, die mit dem Chemikalienverbot entstehen. Deut. Müller-Ztg. 55 (25/26): (Dec. 18, 1957).

——— 139

[Conditioning Problems.] Konditionierungsprobleme. [Abstract in Die 8. Jugenheimer Diskussionstagung. Mühle 95(14): 182-185 (April 3, 1958).]

——— and Hoffmann, H. J. 140

[Measuring Temperatures in a Grain Kernel.] Temperaturmessung im Getreidekorn. Müllerei 5(28): 56-62 (1952). [Also in Mühle 89(27): 435-441 (July 3, 1952) and in 421, pp. 36-45.]

Cosse, S. 141

[The Behavior of Moisture in the Grain Kernel During Conditioning and Drying.] Das verhalten der Feuchtigkeit im Getreidekorn während der Konditionierung und Trocknung. Müllerei 5(12): 181-183 (Mar. 22, 1952). [Also in Ital. e i Cereali 6: 250-252, 257-258 (May 1951).]

Costa, Oswaldo de Almeida. 142

[A Contribution to the Study of the Maturing of Flours. Action of the "Conditioner" on the Chemical Composition of Wheat.] Contribuição ao estudo da maturação das farinhas. Acção do "Preparador" sobre a constituição chimica do trigo. Rev. Alimentar (Rio de Janeiro) 1: 186-188 (1937).

Czyzewsky, B. 143

[The Effect of Conditioning on the Enzymatic Relations in Milling Stock.] Der Einfluss der Konditionierung auf die enzymatischen Verhältnisse im Mahlgut. Mühle 70(22): 559-562 (June 1, 1933).

——— 144

[Conditioning, a Correction of the Natural Condition of Ripeness.] Die Konditionierung, eine Korrektur der Reifebedingungen. Mühle 70(45): 1,161-1,164 (Nov. 9, 1933).

Dalibor. 145

[Say, What is Theory?...What is Practice?...] Sag', was ist denn Theorie?...Doch was ist Praxis?... Z. ges. Getreidew. 25(6): 113-118 (1938).

Dalin, David. 146

The Vacuum Method of Conditioning and Tempering Grain for Storage And Milling. Assoc. Oper. Millers Bul., pp. 816-818 (July 1937). [Also in 40, v. 2, pp. 52-58; and Northwest. Miller 191: 43 (July 14, 1937).]

Dedrick, B. W. 147

Wheat Washing, Conditioning and Blending. In his Practical Milling, pp. 71-96. Natl. Miller, Chicago (1924).

——— 148

[Conditioning and Its Effect on the Milling Process. Results From Experiments and Research on Conditioning Wheat Under Various Conditions.] Das Konditionieren und seine Wirkung beim Mahlvorgange. Ergebnisse von Versuchen und Forschungen über das Konditionieren des Weizens unter wechselnden Bedingungen. Mühle 65(14): 418-419 (Apr. 5, 1928).

Demidov, P. G. 149*

[Conditioning of Hard Wheat.] Trudy Odesskogo Inst. Tekhnol. Zerna i Muki im I. V. Stalina, pp. 21-38 (1938). [In Russian. English title from Chem. Abs. 34: 1,085 (1940).]

Dienst, Karl. 150

[Temperature--Heat and Time as Factors in Vacuum Conditioning.] Temperature--Wärme und Zeit bei der Vakuumvorbereitung. Mühle 75(24): 659-660 (June 17, 1938).

Dienst, Karl. 151

[Processes and Effects of the Treatment of Grain by Hot Air and Under Vacuum.] Vorgänge und Wirkungen bei der Heissluft- und bei der Vakuumbehandlung des Getreides. Z. ges. Getreidew. 26(3): 41-48 (Mar. 1939).

———— 152

[Conditioning.] Konditionierung. Z. ges. Getreidew. 26(5): 103-105 (1939).

———— 153

[Processes and Effects of Conditioning with Different Apparatus.] Vorgänge und Wirkungen bei der Konditionierung in verschiedenartigen Konditionierungsapparaten. Mühle 76(51): 1,083-1,085 (Dec. 22, 1939).

———— 154

[The Vapor as a Medium in the Vacuum Conditioning of Grain and its Influence on Baking Quality.] Der Brüden als Medium bei der Vakuumbehandlung ges Getreides und sein Einfluss auf die Backfähigkeit. Z. ges. Getreidew. 29(4): 54-57 (1942).

———— 155

[Vacuum Conditioning.] Vakuum-Konditionierung. Getreide, Mehl u. Brot 3(9/10): 91-93 (1949). [English abstract in Miller (London): 748 (Aug. 1, 1949).]

———— 156*

[Between Silo and First Break.--Basic Information on the Problem of Washing, Resting and Conditioning.] Müllerei 3(9): (1950). [In German. Through 161.]

———— 157

[Basic Problems of Vacuum Conditioning.] Die Grundlagen der Vakuum-Behandlung. Mühle 88(4): 51-54 (Jan. 25, 1951).

———— 158

[The Effect of Vacuum Conditioning on the Degree of Fineness of Flour.] Der Einfluss der Vakuum-Konditionierung auf den Feinheitsgrad der Mehle. Mühle 88(31): 505-506 (Aug. 2, 1951).

———— 159

[Complete Conditioning of Grain by the Simplest Means With Vacuum Treatment.] Vollständige Konditionierung von Getreide mit einfachsten Mitteln durch Vakuumbehandlung. Mühle 89(8): 113-114 (Feb. 21, 1952).

———— 160

[Conditioning and Milling of Mixtures of Hard and Soft Wheat.] Vorbereitung und Vermahlung von Mischungen mit harten und weichen Weizen. Müllerei 5(8): 109-110 (Feb. 23, 1952).

———— 161

[Flow Sheets for Automatic Grain Cleaning and Grain Conditioning.] Automatische Diagramme für die Getreidereinigung und Getreidevorbereitung. Müllerei 5(28): 51-52 (July 12, 1952).

———— 162

[Schedule for Vacuum Conditioning of Mixtures of Hard and Soft Wheat.] Schema zur Vakuum-Vorbereitung für die Vermahlung von Mischungen harter und weicher Weizen. Mühle 89(37): 581 (Sept. 11, 1952).

———— 163

[Wet Scouring of Grain in Connection With Vacuum Treatment.] Nassschälung von Getreide in Verbindung mit der Vakuumbehandlung. Müllerei 5(47): 735 (Nov. 22, 1952).

———— 164

[Combine-Harvested Bread Grain and Vacuum Drying.] Mähdrusch-Brotgetreide und Vakuumtrocknung. Mühle 90(19): 258 (May 7, 1953).

Dienst, Karl. 165
[Six Variations of the Complete and Continuous Conditioning of Wheat by the Vacuum Method, Including the Outer-Layer Treatment.] Sechs Varianten der vollständigen und kontinuierlichen Weizen-Konditionierung im Vakuumverfahren einschliesslich der Randzonenbehandlung. Müllerei 7(11): 113-114 (Mar. 13, 1954).

Dietz, R. 166
[Individual Conditioning in Medium-Sized and Small Mills.] Die individuelle Vorbereitung in Mittel- und Kleinmühlen. Mühle 70(45): 1,183-1,184 (Nov. 9, 1933).

——— 167
[Moisture of Flour and Grain as an Important Factor in the Milling Process.] Die Feuchtigkeit von Mehl und Getreide als wesentlicher Faktor des Vermahlungsprozesses. Müllerei 4(15): 25-29; (23): 43-48; (30): 53-56 (Apr. 14, July 28, 1951).

Dillman, A. C. 168
Hygroscopic Moisture of Flax Seed and Wheat and its Relation to Combine Harvesting. Amer. Soc. Agron. Jour. 22: 51-74 (1930).

Disney, R. W. 169
The Specific Heat of Some Cereal Grains. Cereal Chem. 31(3): 229-239 (1954).

Doherty, V. E. 170
K. W. Hours per Barrel Required for Different Lengths of Temper. In Wichita District Meeting. Natl. Miller 31(3): 40-41 (Mar. 1926).

Dostal, Alois. 171
[Principles of the Grain Conditioner.] Grundsätzliches vom Getreidevorbereiter. Mühle 69(46): 1,193 (Nov. 17, 1932).

Drake, A. J. 172
A Wheat Tempering "Ratio." Amer. Miller 75(2): 30-32 (Feb. 1947).

Dricot. 173
[The Conditioning of Grain After Damage in Harvesting by Threshing.] Le conditionnement des grains après moissonage-battage. Cong. Internatl. des Indus. Agr. [Rap.] 8(2): 374 (1950).

Dunham, R. W. 174
The Conditioning of Wheat. An Important Contribution to a Controversial Subject. Can Water go Through Bran? Milling (Liverpool) 64(22): 677-678 (May 30, 1925).

E., D. 175
[Cleaning, Scouring and Breaking up of Bread Grain. How Much Cellulose-Free Flour can be Extracted From the Grain?] Reinigen, Schälen und Aufschliessen von Brotgetreide. Wieviel zellulosefreies Mehl kann aus dem Getreide gewonnen werden? Mühle 70(29): 724-725 (July 20, 1933).

Eckhardt, O. 176
[Investigation of Cereal Grains and Flour.] Getreide- und Mehluntersuchung. Moritz Schäfer, Detmold (1957).

Eggers, C. F. 177
The Yield and Tempered Wheat. Amer. Miller 70(11): 28-29 (Nov. 1942).

El-Gindy, M. M., and Schäfer, W. 178
[Further Studies on Differential Staining of Variously Conditioned Wheat Kernels.] Weitere Studien zur färberischen Differenzierung unterschiedlich konditionierter Weizenkörner. Mühle 94(32): 406-408 (Aug. 8, 1957). [Also, with title "Some Microscopic Changes in the Aleurone Layer of Wheat During Conditioning." Cereal Sci. Today 3(3): 61-63 (Mar. 1958).]

Elias, D. G., and Scott, R. A. 179
Recent Advances in British Flour Milling Technology. Cereal Sci. Today 2(7): 180-184 (Sept. 1957). [Similar title in Milling (Liverpool) 129(9): 240-242, 244 (Aug. 31, 1957).]

Eppig, Rudolf. 180
[Preparation or Conditioning.] Die Vorbereitung oder Konditionierung. Deut. Müller-Ztg. 51(11): 250-251 (May 27, 1953).

Eran, P. 181
[Control of Conditioning. A Simple Method for Determination of Distribution of Moisture in the Grain.] Kontrolle des Vorbereitungseffektes. Eine einfache Methode zur Feststellung der Feuchtigkeitsverteilung im Korn. Mühle 90(47): 705-706 (Nov. 19, 1953).

Eschhaus, K. E. 182
[Tempering in Small Mills.] Mahlvorbereitung in Kleinmühlen. Müllerei 5(4): 52 (Jan. 26, 1952).

F., E. 183
[Wheat Conditioning Without a Washer.] Weizenvorbereitung ohne Wäscherei. Mühle 69 (38): 983 (1932).

——— 184
[Grain Cleaning and Conditioning. Influence of Cleaning on Milling and Marketing of the Flour.] Die Gertreidereinigung und -vorbereitung. Einfluss der Reinigung auf Vermahlung und Absatz der Mehle. Mühle 70(7): 157 (Feb. 16, 1933).

F., J. 185
[How Shall I Condition Wheat?] Wie konditioniere ich den Weizen? Mühle 66(1): 9 (1929).

Fairbrother, T. H. 186
Studies in Cereal Chemistry. IV. The Role of Moisture in Wheat and Flour. V. The Conditioning of Wheat. Indus. Chem. and Chem. Mfg. 5: 243-245, 281-285 (June, July 1929).

——— 187
The Influence of Environment on the Moisture Content of Flour and Wheat. Cereal Chem. 6(5): 379-395 (Sept. 1929).

Fairclough, David, and Thomas, J. O. 188
Washing Water--Effluent Recovery--Conditioning. In The Correspondence Course. Milling (Liverpool) 91: 490, 492, 494 (Oct. 22, 1938).

Farrell, E. F. [P.] 189
Tempering Time and Rate of Water Absorption in Wheat. Amer. Miller 63(1): 28-30, 76 (Jan. 1935).

Fejezet, V. 190†
[The Conditioning of Wheat.] A gabona kondicionálása. In Ja.N. Kupric, Malomipari technologia, pp. 149-197. [Hungarian translation by Jozsef Szasz.] Budapest, Elelmiszer Ipari Es Begyujtesi, Konyv, Es Lapkiado Vallalat (1954).

Fisher, E. A. 191
Flour Quality. Its Nature and Control. Technical Education Series. Pamphlet No. 3, 56 pp. London, National Joint Industrial Council for the Flour-Milling Industry (May 1929).

——— and Hines, S. F. 192
Observations on the Rate of Movement of Water in Wheat. Cereal Chem. 16(5): 584-598 (Sept. 1939).

——— and Jones, C. R. 193
A Note on Moisture Interchange in Mixed Wheats, With Observations on the Rate of Absorption of Moisture by Wheat. Cereal Chem. 16(5): 573-583 (Sept. 1939).

Fitzgibbon, Gerald. 194
British Wheat Conditioning Methods. An Authoritative Account of Modern British Methods of Conditioning Wheat, With Particular Emphasis on the Application of Water. Amer. Miller 48(5): 494-495; (8): 872-873 (May, Aug. 1920).

Flechsig, J. 195
[Graphic Table to Determine Addition of Moisture and Loss of Moisture.] Graphische Tafel zur Ermittlung der Feuchtigkeitszugabe und des Feuchtigkeitsverlustes. Mühle 89(24): 355-356 (June 12, 1952).

Fleurent, E. 196
[II. Observations on Cold Milling.] II. Betrachtungen über das Kälte-Mahlverfahren. [Translation by Rudolf Rüter of paper by Fleurent in "La Meunerie Française" 44(456): (Feb. 1928).] Z. ges. Mühlenw. 4(12): 220-221 (Mar. 1928).

Foerster, G. 197
[Moisture and Temperature Increase in the Steaming of Grain.] Feuchtigkeits- und Temperaturzunahme beim Dämpfen von Getreide. Mühle 93(38): 545 (Sept. 20, 1956).

Forster, T. E., Jr. 198
Conditioning. In Conditioning, Forster's AOM topic. Amer. Miller 84(12): 22 (Dec. 1956).

Forster, W. E. 199
Wheat Conditioning. In 40, v. 2, pp. 294-298.

Fr. 200
[More Practical Evidence for the Effect of Conditioning!] Mehr praktische Belege für die Erfolge der Vorbereitung! Mühle 69(51): 1,332 (1932).

Fraser, C. W., and Haley, W. L. 201
Factors That Influence the Rate of Absorption of Water by Wheat. Cereal Chem. 9(1): 45-49 (Jan. 1932).

Fredel, M. M. 202
Technical Trends of 1939--on Developing the Mill Mix--and Tempering. Amer. Miller 67(1): 74 (Jan. 1939).

Fritsch, Eugen. 203
[In What Way Does Water Enter Into the Grain Kernel?] Auf welchem Wege dringt Wasser in das Getreidekorn? Mühle 76(51): 1,081-1,083 (Dec. 22, 1939). [Similar article in 421, pp. 127-128.]

________ 204
[The Openings for Entrance of Water in Leguminous Seeds and in the Cereal Grain Kernel.] Die Wassereintrittsöffnungen bei Hülsenfrüchten und am Getreidekorn. Mühlenlaboratorium 10(9): 98, 100, 102, 104, 106 (Sept. 1940). [Similar article, with title "Wo dringt Wasser in das Getreidekorn?," in 421, pp. 135-137. From Mühle 76: (1939).]

________ 205
[Entrance of Water into the Grain Kernel During Dampening for Milling.] Die Wassereindringung in das Getreidekorn bei müllerisch-technischen Netzungsverfahren. [In 421, pp. 128-131.] From Mühle 77(6): (1940).

________ 206
[Why Should One Give an Outer-Layer Treatment to the Whole Grain Kernel?] Warum Randzonenbehandlung am ganzen Getreidekorn? Mühle 77(9): 101-103 (Mar. 1, 1940).

________ 207
[Characteristics of the Outer-Layer Method.] Charakteristisches des Randzonenverfahrens. [In 421, pp. 132-134.] From Mühle 77(25): (1940). [Similar title in Mühlenlaboratorium 10(3): 21 (1940); and Allg. deut. Mühlen-Ztg. 44(32): 229 (1941).]

________ 208
[Artificial Gluten Hardening as Evidence for the Inadequacy of the Formerly Used Wet Gluten Estimation. A Contribution to the Knowledge of Wet Gluten and its Estimation.] Die künstliche Kleberhartung als Beweis für die Unzulänglichkeit der bisher gebräuchlichen Nasskleberbeurteilung. Ein Beitrag zur Kenntnis des Nassklebers und seiner Bewertung. Mühlenlaboratorium 10(12): 147-152 (1940).

Fritsch, Eugen. 209

[New Ways of Chemically Treating the Kernel.] Neue Wege zur chemischen Kornbehandlung. [In 421, pp. 137-139.] From Allg. Mühlenmarkt, Wien, No. 525: (1941).

——— 210

[Even or Uneven Distribution of Water in the Cereal Grain Kernel Before Milling?] Gleichmässige oder ungleichmässige Wasserverteilung im Getreidekorn vor der Vermahlung? Mühle 78(5): 71-75 (Jan. 31, 1941).

——— 211

[Vacuum Technique and the Cereal Grain Kernel, Today and in the Future.] Vakuumtechnik und Getreidekorn heute und in der Zukunft. Mühle 78(9): 135-136 (Feb. 28, 1941).

——— 212

[New Knowledge in the Experimental Field of the Evacuation of the Cereal Grain Kernel.] Neue Erkenntnisse auf experimentellem Gebiet am evakuierten Getreidekorn. Mühlenlaboratorium 11(3): 37-46 (1941). [Also in Mühle 78(10): (1941).]

——— 213

[A New Basis for Grain and Flour Improvement.] Die Getreide- und Mehlverbesserung auf neuer Grundlage. Mehl u. Brot 43(6): 53-55 (Feb. 5, 1943).

——— 214*

[Can the Original Baking Quality of a Grain Variety be Found Again in its Flour?] Ist die ursprüngliche Backfähigkeit einer Getreidesorte in ihrem Mehl wiederzufinden? Allg. deut. Mühlen-Ztg. (Feb. 10, 1944). [Through 216.]

——— 215*

[The Germ of the Grain as Activator in Conditioning.] Der Getreidekeimling als Aktivator bei der Vorbereitung. Müllerei 3(50): (Dec. 16, 1950). [Through 221.]

——— 216

[Artificially Induced Phase Shifting in the Enzyme Economy of the Kernel and the Flour. A Contribution to the Problem of Cereal Grain Conditioning.] Künstlich erzwungene Phasenverschiebungen im Fermenthaushalt des Kornes und der Mehle. Beiträge zu dem Problem der Getreidevorbereitung. Wiss. Müllerei No. 2: 9-13. In Müllerei 4(7): (Feb. 17, 1951).

——— 217

[The Bran Layers of the Cereal Grain Kernel and Their Significance for Milling, with Special Consideration of the Hyaline Layer.] Die Schaleschichten des Getreidekornes und ihre Bedeutung für die Müllerei unter besonderer Berücksichtigung der hyalinen Schicht. Wiss. Müllerei No. 7: 49-52; No. 8: 60-64. In Müllerei 4(30); (34): (July 28, Aug. 5, 1951).

——— 218

[Absorption or Capillarity Theory? A Contribution to the Hydrotechnique of the Cereal Grain Kernel.] Aufsaug- oder Kapillarthese? Ein Beitrag zur Hydrotechnik am Getreidekorn. Wiss. Müllerei No. 3: 45-48; No. 4: 49-56. In Müllerei 5(12); (17): (Mar. 22, Apr. 26, 1952).

——— 219

[The Mellowing of the Cereal Grain Kernel and its Foundation in Structure.] Die Mürbung des Getreidekornes und ihre statischen Grundlagen. Wiss. Müllerei No. 10: 73-80. In Müllerei 6(43): (Oct. 24, 1953).

——— 220

[Concerning the Outer-Layer Treatment.] Über die Randzonenvorbereitung. [Abstract in Die 6. Jugenheimer Diskussionstagung. Mühle 92(13): 145-146 (Mar. 31, 1955).]

——— 221

[Milling Technology and its Principal Problems in 1955.] Die müllerische Technologie und ihre Kernprobleme im Jahre 1955. Müllerei 8(52): 733-735 (Dec. 24, 1955).

Fritsch, Eugen. 222
[The Efficient Utilization of the Work of the Plant Laboratory.] Die wirtschaftliche Auswertung der Arbeit des Betriebs-laboratoriums. Mühle 93(44): 642-645 (Nov. 1, 1956).

Fritsch, Eugen, and Cleve, H. 223
[Grain Conditioning by the Outer-Layer Process (Process According to Miag, Wille, Fritsch Patent).] Die Getreidevorbereitung nach dem Randzonenverfahren. (Verfahren nach patenten Miag, Wille, Fritsch.) [In 421, pp. 13-15.] Also in Müllerei 4(29): 11-12 (July 21, 1951); and, by Fritsch only, in Mühle 88(28): 451-452 (July 12, 1951). [Abstract in Deut. Müller-Ztg. 49(21): 529-530 (Oct. 17, 1951).]

Fritzenschaft, Eug. 224
[The Use of Vacuum in Drying and Conditioning Wheat.] Einiges über den Betrieb von Vakuumapparaten bei der Getreidetrocknung und -vorbereitung. Mühle 78(50): 815-816 (Dec. 12, 1941).

_________ 225
[Better Storage Quality, Millability, and Flour Quality Through Conditioning of Grain.] Bessere Lagerfähigkeit, Mahltechnik und Mehlqualität durch Vorbereitung des Getreides. Jahrb. der Müllerei: 19-24 (1951).

_________ 226*
[Improvement of Quality Through Conditioning.] Qualitätssteigerung durch Konditionieren. Müllerei u. Bäckerei (Leipzig) (5): (1953). [Through 227.]

_________ 227
[Grain Conditioning.] Getreidevorbereitung. Jahrb. der Müllerei 59: 85-90 (1955).

G., J. (Tunis). 228
[Experiences with the Wheat Conditioner.] Erfahrungen mit dem Weizenvorbereiter. Mühle 67(9): 240-241 (1930).

Galter, E. 229
[The Conditioning Problem: Reflecting and Summing up.] Das Konditionierungsproblem: Querschnitt und Bilanz. Mühle 70(45): 1,177-1,180 (Nov. 9, 1933).

Galter, Eberhard. 230
[Optimum Moisture Content and Hardness for Milling.] Optimale Mahlfeuchtigkeit und Mahlhärte. Deut. Müller-Ztg. 49(9): 224 (May 2, 1951).

Gane, R. 231
The Water Content of Wheats as a Function of Temperature and Humidity. Soc. Chem. Indus. Jour. (London) 60: 44-46 (Feb. 1941).

Gay, F. J. 232
The Effect of Temperature on the Moisture Content-Relative Humidity Equilibria of Wheat. Austral. Council Sci. & Indus. Res. Jour. 19: 187-189 (May 1946).

Geddes, W. F. 233
Chemical and Physico-Chemical Changes Induced in Wheat and Wheat Products by Elevated Temperatures. I. Canad. Jour. Res. 1(6): 528-558 (Dec. 1929). [Abstract in Milling 74: 758-759 (June 28, 1930).]

Gehle, Heinz. 234
[Further Ideas on Wheat Conditioning.] Weitere Ausführungen zur Weizenvorbereitung. [In 421, pp. 88-90.] From Z. ges. Mühlenw. No. 3: (June 1927).

_________ 235
[Milling Technique. The Preparation of the Milling Stock.] Mühlentechnik die "Vorbereitung" des Mahlgutes. Mühle 64(11): 337-339; (15): 458-461; (28): 866-868 (1927).

_________ 236
[Changes in Wheat From Conditioning and Their Utilization in Measurement and Control of the Treatment.] Die Veränderungen des Weizens durch die Vorbereitung und ihre Ausnutzung zur Messung und Kontrolle der Behandlung. Z. ges. Mühlenw. 4(12): 203-205 (March 1928).

Gehle, Heinz. 237

[The Main Parts of the Wheat Conditioner.] Die wichtigsten Teile des Weizen-Vorbereiters. [In 421, pp. 91-94.] From Z. ges. Mühlenw. (Oct. Nov. 1928).

——— 238*

[Further Ideas on Wheat Conditioning.] Weitere Ausführungen zur Weizenvorbereitung. Z. ges. Mühlenw. 5: 124-125, 142-144 (Nov. 1928). [Through Chem. Zentr. 1929: I-703.]

——— 239

[Further Ideas on Wheat Conditioning.] Weitere Ausführungen zur Weizenvorbereitung. Mühle 66(6): 159-161; (11): 329-332; (26): 791-794 (Feb. 7, June 27, 1929). [Also in 421, pp. 99-102, 102-105, 85-88.]

——— 240

[The Role of Moisture in Conditioning of Grain.] Die Rolle der Feuchtigkeit bei der Vorbereitung des Getreides. Z. ges. Mühlenw. 6(3): 40-44 (June 1929).

——— 241

[How High a Temperature May the Hot Air Have in the Drying of Grain?] Wie warm darf die Heissluft beim Getreidetrocknen sein? [In 421, pp. 106-108.] From Mühle 66(38): (1929).

——— 242

[Should I Install a Wheat Conditioner?] Soll ich einen Weizenvorbereiter einbauen? Mühle 66(50): 1,537 (1929).

——— 243

[What are the Temperature Limits When Drying Grain with Hot air?] Wie warm darf die Heizluft beim Getreidetrocknen sein? Mühle 67(3): 62 (1930).

——— 244

[New Auxiliary Equipment for Wheat Conditioning.] Neue Hilfsapparate für die Weizenvorbereitung. [In 421, pp. 77-80.] From Z. ges. Mühlenw. No. 4: (1930).

——— 245

[Tempering and Tempering Apparatus.] Netzen und Netzapparate. Mühle 67(36): 1,005-1,008 (1930).

——— 246

[The Conditioning of Wheat Before Milling. A Reply to the Article in Nos. 10 and 11.] Die Vorbereitung des Weizens vor der Vermahlung. Eine Entgegnung zum Aufsatz in Heft 10 u. 11. Mühle 68(14): 382-385 (Apr. 2, 1931).

——— 247

[Conditioning of Grain. An Answer and a Supplement.] Das Vorbereiten des Getreides. Eine Entgegnung und Ergänzung. Mühle 68(52): 1,423-1,428 (Dec. 24, 1931).

——— 248

[Theory and Practice of Conditioning. An Answer and a Supplement.] Theorie und Praxis in der Getreidevorbereitung. Eine Entgegnung und Ergänzung. Mühle 69(32): 828-829 (Aug. 11, 1932).

——— 249

[Wheat Conditioning. An Answer and a Supplement.] Weizenvorbereitung. Eine Entgegnung und Ergänzung. Mühle 70(9): 204-206 (Mar. 2, 1933).

——— 250

[Warm Air Conditioner or Radiator Conditioner?] Warmluft- oder Radiatorenvorbereiter? Mühle 70(13): 309-311 (Mar. 30, 1933).

——— 251

[Wheat Conditioning.] Weizenvorbereitung. [In 421, pp. 73-76.] From Mühle 70(22): 543-548 (June 1, 1933).

Gehle, Heinz. 252

[New Questions on the Conditioning of Wheat.] Neue Fragen der Weizenvorbereitung. [In 421, pp. 67-73.] From Mühlenlaboratorium, Sonderausgabe (June 21, 1933).

——— 253

[The Physical Behavior of the Wheat Kernel During Drying and Conditioning. An Answer.] Das physikalische Verhalten des Weizenkornes beim Trocknen und Konditionieren. Eine Ergänzung. Mühle 70(45): 1,155-1,158 (1933). [Slightly shortened, in 421, pp. 111-114.]

——— 254

[Spray-Dampening, and What We Learn From it For Treatment of the Grain Before the Milling Process.] Bestäubungsnetzung und ihre Lehren für die Behandlung des Getreides vor der Vermahlung. [In 421, pp. 81-84.] From Z. ges. Getreide-, Mühlen- u. Bäckereiw., No. 2: (1933).

——— 255

[Laboratory Tests that Lead to an Improvement in Baking Quality.] Laboratoriumsversuche, die zur Verbesserung der Backfähigkeit führen. [In 421, pp. 119-123.] From Allg. deut. Mühlen-Ztg. No. 25: (1935).

——— 256

[Grain Conditioning. A Review with Numerous References to Earlier Practices.] Getreide-Vorbereitung. Ein Rückblick und Ausblick mit zahlreichen Hinweisen auf frühere Ausführungen. [Abstract in 421, pp. 124-125.] From Mühle 72(33): 1,027-1,030 (Aug. 16, 1935).

——— 257

Storage, Drying, and Conditioning of Grain. [In 420, pp. 48-65. A portion also in 421, pp. 115-119.] From Mühle 71(43): (1934).

——— 258

[Where Do We Stand on Wheat Conditioning?] Wo stehen wir in der Weizenvorbereitung? Mühle 75(22): 609-612 (June 3, 1938).

——— 259

[The Problems of Grain Conditioning.] Die Probleme der Getreide-Vorbereitung. [In 421, pp. 1-6.] From Müllerei 4(29): (1951).[Also in Mühle 88(28): 447-449 (July 12, 1951.]

——— 260

[The Status of Conditioning, and its Most Important Apparatus in the World Market About the Middle of the Century. A Condensed Review of Presentations at Meetings of Miag.] Über den Stand der Konditionierung und die wichtigsten Apparaturen des Weltmarktes um die Jahre Mitte des Jahrhunderts. Zusammenfassende Übersicht nach Vorträgen auf Vertretertagung der Miag. In 421, pp. 7-13.

——— 261

[Retrospect and Prospect.] Rückblick und Ausblick. [In 421, pp. 15-19.] From Miag Nachrichten (Jan. 1952).] [Translation in Miag Nachrichten, English edition, second issue, pp. 19-22 (1953).]

——— 262

[The Conditioning of Grain.] Die Vorbereitung des Getreides. [Panel discussion by Altrogge, Cleve, and Schäfer.] Mühle 90(28): 414-421 (July 9, 1953).

——— 263

Wheat Conditioning and Drying. Northwest. Miller 253(10), Sect. 2: 6a-7a (Mar. 8, 1955).

——— 264

Wheat Conditioning. Assoc. Oper. Millers Bul., pp. 2,147-2,152 (March 1955). [Reviewed in Northwest. Miller 251(22): 59 (June 1, 1954); Amer. Miller 82(7): 25, 28 (July 1954); Milling (Liverpool) 123: 294, 296 (Sept. 11, 1954); Milling World Wide (Sept. 1954); and Müllerei 7(43): 584 (Oct. 23, 1954).]

Gehle,Heinz. 265

The Practical Results of Research. In Miag Nachrichten, pp. 1-4 (Dec. 1954).

——— 266

[Possibilities for Milling After the Prohibition of Chemical Treatment.] Müllerische Möglichkeiten nach dem Behandlungsverbot. [Abstract in Müllerei-Tagung in Detmold 1957. Mühle 94(43): 553-556 (Oct. 24, 1957).]

——— and Cleve, H. 267

Report on Conditioning North American Wheats. [Address presented by Peter Goldberg at 42nd meeting of AACC.] Northwest. Miller 259(6), Sect. 2: 1a, 7a-8a, 10a (Feb. 11, 1958); and Milling Prod. 23(2): 1, 9-10, 12 (Feb. 1958). [Similar article with title "Konditionierung von Qualitätsweizen," in Mühle 95(2): 16-18 (Jan. 9, 1958). Summary in Northwest. Miller 257(24), Sect. 2: 10a-11a (June 11, 1957).]

——— and Hoffmann, H. J. 268

[Further Constructive Development of the Radiator Conditioner. An Answer and a Supplement.] Die konstruktive Weiterentwicklung des Radiatoren-Vorbereiters. Eine Entgegnung und Ergänzung. [In 421, pp. 32-35.] From Müllerei 5(7): 93-95 (Feb. 16, 1952).

——— and Will. 269

[Effect of Heat on the Gluten Properties and Baking Quality of Wheat.] Über die Einwirkung der Wärme auf die Kleberbeschaffenheit und Backfähigkeit des Weizens. Mühle 75(6): 143-147 (Feb. 11, 1938). [Similar title in 421, pp. 65-67, from Allg. deut. Mühlen-Ztg. No. 6: (1938).]

Geoffroy, R. 270

[Water in the Cereal Industries.] L'eau dans les industries des céréales. Bul. Anciens Élèves École Franç. Meun. No. 143: 195-199 (Sept./Oct. 1954).

Gillespie, Alex. 271

Throwing new Light on Wheat Tempering. Some Facts not Generally Known and a Proposed new Method of Moistening the Bran and Mellowing the Endosperm. Natl. Miller 31(8): 15-17 (Aug. 1926). [Also in Mühle 63(42): (1926).]

——— 272

How is Milling to be Further Improved? Amer. Miller 56(7): 763-768 (July 1, 1928).

——— 273

The Importance of Time Tempering. Northwest. Miller 233(10), Sect. 2: 18a-19a (Mar. 9, 1948). [Also in Milling Prod. 13(3): 22 (1948).]

Giuseppe, Mozzone. 274

[The Preparation of Grain for Milling. Conditioning.] Della preparazione del grano alla macinazione. Il condizionamento. Selezione di Tec. Molitoria 7(2): 43-44; (3): 96-98; (5): 79, 82 (Feb.-May 1956).

Grammelsberger, Jos. 275

[Cleaning and Milling Results with Normal Wheat and Wheat Scoured Half-Damp.] Reinigungs- und Mahlergebnisse mit normal und halbfeucht geschältem Weizen. Müllerei 4(35): 569 (Sept. 1, 1951).

——— 276

[Simultaneous Conditioning of Wheat of Dissimilar Structure.] Gemeinsames Konditionieren von Weizen mit unterschiedlicher Struktur. Müllerei 5(13): 198-199 (Mar. 29, 1952).

——— 277

[Appropriate Grain Conditioning and Power Requirement.] Zweckentsprechende Getreidekonditionierung und Kraftbedarf. Müllerei 5(20): 321 (May 17, 1952).

Grischenko, A. P. 278

The Percentage Composition of the Wheat Kernel and the Ash Content of its Constituents. [Translated from Mühlenlaboratorium 5: 182-188 (1935) by Clinton L. Brooke.] Northwest. Miller [n.d.].

Greer, E. N., Hinton, J. J. C., Jones, C. R., and Kent, N. L. 279
The Occurrence of Endosperm Cells in Wheat Flour. Cereal Chem. 28(1): 58-67 (1951).

Grobe. 280
[Should the Owner of the Small Mill Use Conditioning?] Soll auch der Kleinmüller konditionieren? Mühle 89(32): 516 (Aug. 7, 1952).

Gröbner. 281*
[How Should I condition Wheat?] Wie konditioniere ich den Weizen? Mühle 65(48); (51); 66(1): (1928-1929). [Through 318.]

Grosh, G. M., and Milner, Max. 282
The Penetration of Moisture into the Wheat Kernel. Northwest. Miller 254(15), Sect. 2: 1a, 19a, 21a - 22a (Oct. 11, 1955). [Also in Milling Prod. 20(10): 1, 21, 23-24 (Oct. 1955).]

——— 283
The Relationship Between Water Penetration and Internal Cracking in Tempered Wheat Grains. Cereal Chem. 36(3): 260-273 (May 1959).

Grosse. 284
[Should I Install a Wheat Conditioner?] Soll ich einen Weizenvorbereiter einbauen? Mühle 66(35): 1,089-1,091 (Aug. 29, 1929).

——— 285
[Research and Experience in Washing and Conditioning Grain.] Versuche und Erfahrungen in der Getreidewäscherei und -vorbereitung. Mühle 66(39): 1,221-1,222 (1929).

H. 286
[On Damping of Grain. Should One Dampen with Warm Water or Warm the Grain?] Vom Netzen des Getreides. Mit Warmwasser netzen oder das Getreide erwärmen? Mühle 67(6): 150-151 (Feb. 6, 1930).

H., E. 287
[On Damping.] Vom Netzen. Mühle 88(24): 388 (June 14, 1951).

H., F. (Italy). 288
[Contribution on Conditioning.] Beitrag über das Konditionieren. Mühle 67(12): 327 (1930).

H., R. (Finland). 289
[Contribution on Conditioning.] Beitrag über das Konditionieren. Mühle 66(2): 40 (1929).

Hachmann. 290
[The Adjustment of the Small Mill After Abolition of the Chemical and Bleaching Agents.] Die Ausrichtung der Kleinmühle nach Wegfall der chemischen Behandlungs- und Bleichmittel. Mühle 94(17): 218 (Apr. 25, 1957).

Hale, W. S. 291
A Review of the 1938 Literature Pertaining to the Field of Cereal Chemistry. Cereal Chem. 16(4): 449-455 (July 1939).

Haltmeier, Otto. 292
Water Penetration in the Wheat Kernel. [Translated from Mühle 70(45): 1,165-1,170 (1933) by Clinton L. Brooke.] Natl. Miller and Amer. Miller 62(5): 35-38 (May 1934).

——— 293
[Hygroscopic Characteristics of Grain and its Milling Products. Moisture Determination by an Inexpensive Method.] Hygroskopische Eigenschaften von Getreide und seinen Mahlprodukten. Feuchtigkeitsbestimmung auf billige Weise. Mühle 71(45): 1,299-1,304 (1934).

——— 294
[Determination of the Conditioning Effect.] Die Feststellung der Konditionierwirkung. Mühle 72(33): 1,037-1,040 (1935).

Haltmeier, Otto. 295
[Water Absorption During Washing of Grain.] Die Wasseraufnahme beim Waschen von Getreide. Mühle 74(39): 1,163-1,166 (Sept. 24, 1937).

Hampel. 296
[Determination of Hardness of Wheat.] Zur Härtebestimmung von Weizen. [Abstract in Getreidechemiker-Tagung 1957 Detmold. Mühle 94(24): 305-306 (June 13, 1957).]

——— 297
[Contribution to Determination of Kernel and Endosperm Hardness.] Beiträge zur Bestimmung der Korn- und Mehlkernhärte. Getreide u. Mehl 7(11): 91-96 (Nov. 1957).

Hardt, G. 298
[Conditioning Without a Conditioner.] Vorbereitung ohne Vorbereiter. In his Veränderungen in Vermahlung, Mehlausbeute und -qualität. Mühle 94(2): 20 (Jan. 10, 1957).

——— 299
[Milling in Winter.] Die Vermahlung in der kalten Jahreszeit. Mühle 94(3): 29 (Jan. 17, 1957).

——— 300
[Conditioning Without a Conditioner--Holding Time.] Vorbereitung ohne Vorbereiter--Abstehzeiten. Mühle 95(7): 92; (8): 106 (Feb. 13,20, 1958).

Hartkopf, Arthur. 301
What About Conditioning? Amer. Miller 66(1): 56-58, 206 (Jan. 1938).

Hauswald, Fritz. 302
[Why do We Dampen Grain?] Warum netzen wir das Getreide? Mühle 88(4): 60 (Jan. 25, 1951).

Heinze, P. 303
[Washing Serves the Miller.] Die Wäscherei im Dienste der Müllerei. Mühle 74(39): 1,165-1,168 (Sept. 24, 1937).

Herd, C. W. 304
Wheat Washing and Conditioning. Miller (London) 63: 714-716 (July 5, 1937).

Hinton, J. J. C. 305
Resistance of the Testa to Entry of Water into the Wheat Kernel. Cereal Chem. 32(4): 296-306 (July 1955).

Hipkow-Zündapp-Werke, Kranz, Wilhelm. 306
Raising the Flour Yield in Grain Milling. German Patent 812,144 (Aug. 27, 1951). [Abstract in Chem. Abs. 47: 6574b (1953).]

Hodler, P. W. 307
The Effect of Splitting Wheat Before Tempering. Amer. Miller 69(2): 25-27 (Feb. 1941).

Hoeft, Karl. 308
[Vacuum Duct Drier and Conditioner. A Proposal for Improvement of Grain Drying and Conditioning.] Vakuum-Schachttrockner und -Vorbereiter. Ein Vorschlag zur Verbesserung der Getreidetrocknung und Vorbereitung. Mühle 70(22): 551-554 (June 1, 1933).

Hoffmann, H. J. 309
[Tables for the Calculation of Thermal Reactions in Conditioning.] Tabellen zur Berechnung von thermischen Vorgängen bei der Vorbereitung. In 421, pp. I-IX.

Hoffmann, H. J. 310

[Drying and Treatment of Grain and Grain Products by Infrared Rays.] Trocknung und Behandlung von Getreide und Getreideprodukten durch infrarote Strahlen. [In 421, pp. 46-48.] From Müllerei 5(29): 481-482 (July 19, 1952).

——— 311*

[The Vacuum Dryer and Conditioner.] Der Vakuum-trocknungs- und -vorbereitungsapparat. Mühle 89(49): 758-759 (Dec. 4, 1952). Through Bibliography Agr. 17: 37642 (1953).

——— 312

[Vacuum Drying and Conditioning.] Vakuumtrocknung und -Vorbereitung. In 421, pp. 58-60.

——— 313

[Comparison of Grain Drying by Preheating with Infrared Rays and with Radiator Driers.] Trocknung von Getreide mit Infrarotvorwärmung oder Radiatorenvorwärmung? Müllerei 7(34): (Aug. 21, 1954).

——— 314

[Primitive Drying or Fast Drying of Grain?] Primitivtrocknung oder Schnelltrocknung von Getreide? Mühle 92(34): 453-455 (Aug. 25, 1955).

——— 315

[Steam in the Steaming of Grain.] Der Dampf beim Dämpfen von Getreide. Mühle 93(33): 467-468 (Aug. 16, 1956).

Hopf, Leo. 316

[The Improvement of Grain by Proper Drying. The Change in Gluten. Effects on Diastatic Power.] Getreideveredlung durch richtiges Trocknen. Die Veränderung des Klebers. Auswirkungen auf die diastatische Kraft. Mühlenlaboratorium 2(10): 58-59; (11): 64-65 (1932).

——— 317

[Cold Milling of Grain. The Cold Method of Loizillon--The Milling Temperature--Diagram and Calculation of Economy of Cold Milling--Effect of Heat and Cold on Gluten.] Getreidekaltvermahlung. Das Kälteverfahren von Loizillon--Die Höhe der Vermahlungstemperatur--Diagramm und Rentabilitätsberechnung einer Kaltvermahlung--Kleberbeeinflussung durch Wärme und Kälte. Mühle 70(39): 993-996; (40): 1,024; (41): 1,045; (42): 1,081-1,082 (Sept. 28-Oct. 19, 1933).

——— 318

[Moisture Exchange During Drying, Conditioning and Milling. The Distinction Between Drying and Conditioning--Does the Kernel Sweat During Conditioning?--Moisture Conditions During Regular Milling and During Cold Milling--The Pneumatic Circuit Conveyor and its Effect on the Moisture of the Stock.] Der Vorgang des Feuchtigkeitsaustausches beim Trocknen, Vorbereiten u. Mahlen. Die Grenze zwischen Trocknen und Vorbereiten--Schwitzt das Korn bei der Vorbereitung?--Die Feuchtigkeitsverhältnisse beim Mahlen bei Normalvermahlung und Kaltvermahlung--Der pneumatische Kreislaufförderer und das Verhalten der Mahlgutfeuchtigkeit in ihm. Mühle 70(45): 1,169-1,178 (Nov. 9, 1933).

——— 319*

[The Physical Behavior of Wheat in Drying and Conditioning.] Das physikalische Verhalten des Weizenkornes beim Trocknen und Konditionieren. Z. ges. Getreidew. 5: (1933).

——— 320

[Further Observations on the Physical Changes in the Wheat During Conditioning. Moistness is not Mellowness--Parallelism Between Research and Practice--The Advanced State of Mellowing in Soft Wheats.] Weitere Ergebnisse über die physikalischen Veränderungen im Weizenkorn beim Vorbereiten. Feuchtigkeit ist keine Mürbung--Die Parallelität der Versuche mit der Praxis--Voreilung der Mürbung bei Weichweizen. Mühle 71(13-16): 343-347, 369-372, 399-400, 423-424 (March, April 1934). [Abstract by C. O. Swanson in Northwest. Miller 181: 194-195 (Jan. 16, 1935).]

Hopf, Leo. 321

[Are the Enzymes of the Kernel Damaged During Conditioning?] Werden die Fermente des Kornes beim Vorbereiten geschädigt? Mühlenlaboratorium 4: 47-50 (1934).

——— 322

[Wheat Mixtures and Mixtures of Flour.] Weizenmischungen und gemischte Mehle. Mühle 72(20): 611-613 (May 17, 1935).

——— 323

[Conditioning of Yesterday and Today.] Konditionieren von gestern und heute. Mühle 72(33): 1,039-1,044 (1935).

——— 324

[Excerpts from the Third Special Number on Conditioning.] Extract aus dem Konditionierungsheft III. Mühle 72(36): 1,129-1,132 (Sept. 6, 1935). [The complete articles are in Mühle 72, No. 33.]

——— 325

[Further Investigations of the Wheat Kernel and Their Relation to Cleaning, Grinding and Conditioning.] Weitere Untersuchungen am Weizenkorn und deren Beziehungen zum Reinigen, Mahlen und Vorbereiten. Mühle 76(41): 971-973; (42): 985 (Oct. 13, 20, 1939).

——— 326

[Difficulties of Tempering in Winter.] Die Schwierigkeiten beim Netzen in der kalten Jahreszeit. Mühle 78(2): 19-20 (Jan. 10, 1941).

——— 327

[Research on Short-Time Conditioning of Wheat (Outer-Layer Process).] Untersuchungsergebnisse über die Kurzkonditionierung von Weizen (Randzonenbehandlung). Müllerei 2(4): 50-52; (5): 66-67 (1949).

——— 328

[Conditioning.] Die Vorbereitung. In his Mühlentechnisches Praktikum Band I, pp. 212-248. Hugo Matthaes, Stuttgart. (1950).

——— 329

[The Production of Better Flour in the Small Mill.] Zur Erzielung besserer Mehle in Kleinmühlen. Müllerei 3: 318-319 (May 27, 1950).

——— 330

[The Milling Moisture Content Before the First Break.] Die Vermahlungsfeuchtigkeit vor dem I. Schrot. Müllerei 6(39): 581 (Sept. 26, 1953).

——— 331

[The Relationship of the Factors Moisture, Color and Yield.] Die Abhängigkeit von den Faktoren Feuchtigkeit, Farbe und Ausbeute. Müllerei 9(7): 81-82 (Feb. 18, 1956).

Hubbard, J. E., Earle, F. R., and Senti, F. R. 332

Moisture Relations in Wheat and Corn. Cereal Chem. 34(6): 422-433 (Nov. 1957).

Hübsch, Otto. 333

[The Wheat Conditioner.] Der Weizenvorbereiter. Mühle 69(14): 348-349 (Apr. 7, 1932).

——— 334

[Grain Conditioning.] Getreidevorbereitung. Mühle 75(22): 611-614 (June 3, 1938).

——— 335

[Conditioning and Maturing of Grain. Can an Improvement in the Baking Quality be Expected from Conditioning According to Present Methods?] Vorbereitung und Reifung des Getreides. Ist mittels der Konditionierung nach dem heutigen Verfahren eine Verbesserung der Backfähigkeit zu erwarten? Mühle 89(49): 760-761 (Dec. 4, 1952).

Humphries, A. E. 336
Some Points Concerning the Treatment of Wheaten Flour. 15 pp. Reprinted from Milling (Liverpool), Sept. 9, 1911.

Ingram, K. 337
Some Aspects of Cold Conditioning. Northwest. Miller 238(5), Sect. 2: 10a-12a (May 10, 1949).

Jago, William, and Jago, W. C. 338
The Technology of Breadmaking Including the Chemistry and Analytical and Practical Testing of Wheat, Flour, and Other Materials Employed in Breadmaking and Confectionery. Simkin, Marshall, Hamilton, Kent, England (1911) and Bakers' Helper, Chicago (1921). Excerpts from 1911 edition quoted in Wheat Tempering, or Conditioning. Northwest. Miller Prod. Ann. Sup. 192: 33 (Oct. 13, 1937).

Janicki, J. 339
[Vital Staining of Aleurone Cells of Grain with Neutral Red.] Vitalfärbung der Aleuronzellen von Getreide mit Neutralrot. [Abstract in Getreidechemiker-Tagung 1957 in Detmold. Mühle 94(24): 305-306 (June 13, 1957).]

———, Debczynska, D., and Koczuk, I. 340
[The Influence of Different Temperatures on the Biochemical Properties of Wheat.] Der Einfluss verscheidenen Temperaturen auf die biochemischen Eigenschaften des Weizens. Getreide u. Meh 8(2): 11-15 (Feb. 1958).

Jones, C. R. 341
The Conditioning of Wheat. The Manner of Entry of Water into the Wheat Grain. Milling (Liverpool) 111(23): 536-537 (Dec. 4, 1948).

——— 342
Observations on the Rate of Penetration of Water into the Wheat Grain. Milling (Liverpool) 113(4): 80-82, 84, 86 (July 23, 1949). [Also in Northwest. Miller 239(11), Sect. 2: 3a-8a (Sept. 13, 1949).]

——— 343
Evaporation in Low Vacuum from Warm Granular Material (Wheat) During the Falling Rate Period. Jour. Sci. Food and Agr. 2(12): 565-571 (Dec. 1951).

——— 344
Recent British Studies of Wheat Conditioning and Drying. Internatl. Bread Cong. [Proc.] 3: 163-166 (1955). [Abstract in Milling Prod. 20(7): 6-8 (July 1955); also in Mühle 92(23): 304-305 (June 9, 1955); and Northwest. Miller 254(2), Sect. 2: 4a-6a (July 12, 1955).]

——— and Campbell, J. D. 345
Micro-Determination of Endosperm Density as a Means of Mapping Moisture Distribution in Wheat Grains. Cereal Chem. 30(3): 177-189 (May 1953).

Keller, Ernst. 346
[Is There a Substitute for Chemical Treatment of Flour?] Gibt es einen Ersatz für die chemische Mehlbehandlung? Mühle 94(16): 204-205 (April 18, 1957).

Kemény, Ander [Andor]. 347
[Heat Treatment of Wheat and of Flour.] Die Wärmebehandlung des Weizens und des Mehles. Z. ges. Mühlenw. 4(12): 205-207 (Mar. 1928).

——— 348
Washing and Conditioning. Natl. Miller 33(6): 18-20, 65-66 (June 1928). [Also in Mühle 65(27): 32 (1928).]

——— 349
[Proposals for Wheat Conditioning.] Vorschlage zur Weizenvorbereitung. Mühle 70(45): 1,177-1,178 (Nov. 9, 1933).

Kent, N. L. 350
The Scientific Principles of Flour Milling. In Food Science, pp. 109-120. University Press, Cambridge, England (1952).

Kent, N. L., Baker, G. J., and Jones, C. R. 351
[Warm Milling of Wheat.] Warmvermahlung von Weizen. [British Patent 723,863] Mühle 92(52): 709 (Dec. 29, 1955).

_______ Baker, G. J., and Jones, C. R. 352
The Effects of Variations in Temperature of the Breaking Process. Milling Prod. 21(8): 1, 17-20 (Aug. 1956). [Also in Northwest. Miller 256(7), Sect. 2: 1a, 15a-18a (Aug. 14, 1956); and Mühle 93(17): 235 (1956).]

Kent-Jones, D. W. 353*
A Study of the Effect of Heat Upon Wheat and Flour, Especially in Relation to Strength. [Thesis, London University (1926).] Through 357, p. 755; abstract, pp. 170-173.

_______ 354
The Improvement of Flour by Physical Methods. Northwest. Miller 151(2): 159-160 (July 13, 1927). [Also in Millers' Rev. 91(8): 24(1927); and Z. ges. Mühlenw. 4: 207-208 (1927).]

_______ 355
Heat Conditioning of Wheat. [Abstract of D. W. Kent-Jones' review of an article by Berliner and Rüter.] Northwest. Miller 154: 1,058 (June 13, 1928).

_______ 356
What Millers Should Know of Chemistry. Wheat Intake, Cleaning, and Conditioning. Northwest. Miller 233(2), Sect. 2: 10a-12a (Jan. 13, 1948).

_______ and Amos, A. J. 357
Conditioning and the Effect of Heat on Wheat and Flour. Investigations on Gluten in Relation to Strength. In their Modern Cereal Chemistry. Ed. 5, pp. 161-175 and 146-149. Northern Publishing Co., Liverpool (1957).

Kettner, Otto. 358
[A Combined Grain Peeling and Conditioning Process.] Kombiniertes Getreideschäl- und Vorbereitungsverfahren. Mühle 72(33): 1043-1046 (1935).

Kick, Friedrich. 359
On Moistening Grain. In his Flour Manufacture. [Translated by H. H. P. Powles from Die Mehlfabrication. Ed. 2, p. 72 (1878).] Lockwood, London (1888).

Kipper, W. 360
[Treatment of Wheat and Rye with Infrared Rays.] Die Behandlung von Weizen und Roggen mit infraroten Strahlen. Mühle 90(13): 171 (Mar. 26, 1953). [Abstract in Deut. Müller-Ztg. 51(7): 151 (Apr. 1, 1953).]

_______ 361
[Use of Infrared Rays in Milling.] Anwendungsmöglichkeiten von Infrarotstrahlen in der Müllerei. [Abstract in Vortrags- und Diskussionstagung des Forschungsinstitutes für Getreidechemie, Darmstadt in Linz/Donau. Mühle 90(41): 615 (Oct. 8, 1953).]

_______ and Rumpf, S. 362
[The Use of Infrared Rays for Conditioning and Drying Grain.] Der Verwendung infraroter Strahlen zur Vorbereitung (Konditionierung) und Trocknung von Getreide. Deut. Müller-Ztg. 52(17): 405-408 (Aug. 18, 1954).

Klimmek, H. 363
[Conditioning Domestic and Foreign Wheat.] Vorbereiten in- und ausländischer Weizen. Müllerei 3: 140-141 (Mar. 11, 1950).

Kliwer, A. G., and Williams, Roy. 364
Wheat Conditioning. Amer. Miller 52(9): 997-998 (1924). [Also in Mod. Miller 52(1): 26 (1924).]

Klug, H. 365
[The Movement of Water in Plant and Kernel.] Wasserbewegung in Pflanze und Korn. Mühle 70(45): 1,181-1,182 (Nov. 9, 1933).

Kohn, Rudolph. 366
Wheat Conditioning--a Comparison of Methods. Northwest. Miller 207(11), Sect. 2: 3a-4a, 6a (Sept. 10, 1941). [Also in Miller (London) 71: 688-690 (Oct. 1, 1945).]

Köster. 367*
[Standardization of Evaluation of Wheat for Industry.] Standardisierung des industriellen Weizenwertes. K. Triltsch, Würzburg (1939). [Through 230.]

Koster, G. 368
[Stepwise Cold Conditioning.] Stufenweise Kaltkonditionierung. Mühle 95(9): 111-112 (Feb. 27, 1958).

Kozmin, N. P. 369
[Critical Contributions to Biochemistry of Conditioning.] Kritische Beiträge zur Biochemie der Konditionierung. Mühle 70(45): 1,159-1,162 (1933).

Kozmin, Peter. 370
Damping the Grain. In his Flour Milling, pp. 143-147. Routledge, London (1917) [Translated from Russian.]

Kranz, W. 371
[Contribution on the Swelling of the Wheat Kernel.] Beitrag zur Quellung des Weizenkorns. Mühlenlaboratorium 2(7): 45-46 (1932).

________ 372
[Extensibility of Gluten. Its Measurement and its Relation to Wheat Conditioning.] Kleberdehnbarkeit. Messmethode und Verhalten bei der Weizenkonditionierung. Mühlenlaboratorium 5(11): 161-166 (Nov. 1935).

________ 373
The Mill Laboratory. In 420, pp. 79-99.

Kretovich, V. L., and Florenskaja, T. C. 374*
[The Influence of Temperature on the Protein and Enzyme Content of Grain.] Inst. Biochem. im A. N. Bacha Akademia Nauk SSSR. [In Russian. Through 340.]

________ and Riazantzeva, E. N. 375
Biochemical Changes in Wheat Grain Under the Action of High Temperatures. Acad. Sci. U.R.S.S. Compt. Rend. [N.S.] 3(9): 409-412 (July-Dec. 1935). [In English.]

Křtinský, Charles. 375a*
Improved Flour Milling After Preceding Chemical Peeling of the Grain. Internatl. Conf. on Flour and Bread Manufacture, Proc. 1. Prague 1927: 76-77 (1929). [Through Chem. Abs. 24: 3,568 (1930).]

Křtinský, K. 376
[Study of the Method of Berliner.] Studium der Methode von Berliner. Mühlenlaboratorium 8: 115-120 (1938).

Kühl, Hugo. 377
[The Conditioning of Wheat and the Colloidal System in Dough.] Die Konditionierung des Weizens und das Kolloide-System in Teige. Mühle 70(45): 1,157-1,160 (Nov. 12, 1933).

________ 378
[The Conditioning of Grain.] Die Konditionierung des Getreides. Chem.-Ztg. 63(54): 469-471 (July 8, 1939).

Kühn, C. 379*
Müllerei 4(39): 635-637 (1951). [Through 581.]

Kuprianoff, Johann. 380

[Food Processing.] Lebensmitteltechnik. Ver. Deut. Ingen. Ztschr. 100(7): 300-304 (March 1, 1958).

Kuprits, IA. N. 381†

[Conditioning of Wheat. Physico-Mechanical Properties of Grain. Moisture of the Grain as a Technological Factor in the Milling Process. Summary of Conclusions.] In his [Physico-Chemical Principles of Flour Milling], pp. 12-103, 169-202. Moscow (1946). [In Russian.]

________ Shpolianskaia, A. L., and Rubina, N. K. 382

[Investigation of Drying and Conditioning Wheat in a Vacuum.] Kolloid. Zhur. 15(3): 198-203 (May/June 1953). [In Russian. English title from Bibliography Agr. 17(10): 91,421 (1953).]

Lawellin, S. J., and Evans, N. G. 383

Wheat and its Preparation. In their Milling Chemistry. Questions and Answers, pp. 15-33. National Miller, Chicago (1925).

Lawson, P. H. 384

Wheat Conditioning. In his Timely Comment. Assoc. Oper. Millers Bul., p. 776 (Feb. 1937).

Legel, Rich. 385

[Wheat Milling in the Small Mill.] Die Weizenmüllerei in Kleinmühlen. Mühle 94(4): 47 (Jan. 24, 1957).

Lehmann, Ernst, and Aichelle, Fritz. 386

[Physiology of Germination of the Grasses (Gramineae).] Keimungsphysiologie der Gräser (Gramineen). Ferdinand Enke, Stuttgart (1931).

Leroy, M. 387

[Methods for the Study of Moist Air and of the Behavior of Grains in Moist Air.] Méthodes d'étude de l'air humide et du comportement des grains dans l'air humide. Bul. Anciens Élèves École Franç. Meun. 136: 155-160 (July-Aug. 1953).

Lindberg, J. E. 388

[Experiments on Heat Treatment of Wheat.] Versuche über die Wärmebehandlung von Weizen. Getreide u. Mehl 3(3): 17-22 (Mar. 1953).

Linder, H. 389

[The Character of Infrared Drying.] Das Wesen der Infrarot-Trocknung. Mühle 91(31): 391-392 (Aug. 5, 1954).

________ Rumpf, [S.], and Kipper, [W.] 390

[Theory and Practice of Drying and Conditioning with Infrared Rays.] Theorie und Praxis der Trocknung und Konditionierung mit infraroten Strahlen. [Abstract in 5. Jugenheimer Diskussionstagung. Deut. Müller-Ztg. 52: 155-157 (Mar. 31, 1954); and Mühle 91(12): 143 (Mar. 25, 1954).]

Lockwood, J. F. 391*

A Comparison of British and American Milling Methods. Simon, Stockport, England (1936). [Through 393.]

________ 392*

Methods of Comparing Milling Results. Simon, Stockport, England (1937). [Through 393.]

________ 393

Conditioning. In his Flour Milling, pp. 189-224. Northern Publishing Co., Liverpool (1945). [German edition. 1951].

________ 394

Conditioning of Wheat for Milling. Northwest. Miller 232(10), Sect. 2: 7a-9a, 12a (Dec. 9, 1947). [Also in Congr. Internatl. des Indus. de Fermentation 1: 432-440 (1947); Miller (London) 77: 341-342 (Oct. 13, 1947); Milling (Liverpool) 109: 304-307 (Oct. 11, 1947); Milling Prod. 12(12): 11 (1947); Abstract by Erich Reimann with title "Ein Neues Getreidevorbereitungsverfahren," in Mühlen-Ztg. 2(16): 85 (July 31, 1948).]

Lockwood, J. F. 395

Various Aspects of Wheat Conditioning in Europe. Assoc. Oper. Millers Bul., pp. 1,784-1,790 (Dec. 1949). [Also in Miller (London) 81 (3,701): 13-18 (Jan. 2, 1950); Abstract in Amer. Miller 77(6): 42,45 (June 1949); and Northwest. Miller 238(11), Sect. 2: 20a-21a (June 14, 1949).]

________ 396*

The Stabilizer Conditioner and Wheat Conditioning in Europe. Milling and Feed 30(7): 18-19, 61 (July 1949). [Probably equivalent to 395. Through G. M. Grosh.]

Loeb, J. 397*

[Studies of Diastatic Phenomena in Wheat Flour.] Études des phenomènes diastasiques dans les farines de froment. Gap (1930). [Through 369.]

Loizillon. 398

[The Use of Artificial Cold in the Milling Industry.] Die Anwendung der künstlichen Kälte in der Mühlenindustrie. [Translation by Charles Jaeger of address by Loizillon to French milling congress.] Z. ges Mühlenw. 4(12): 216-219 (Mar. 1928).

Lorenzen, K. 399

[Conditioning and Drying.] Konditionieren und Trocknen. Mühle 79(47): 729-730 (Nov. 20, 1942).

Losev, N. 400

[Modifications in Grain During Conditioning.] Sovet. Mukomol'e Khiébopechenie 11(4): 9-14 (1936). [In Russian. English title from Chem. Abs. 31: 7,124-6 (1937). Die durch die Konditionierung im Weizen eintretenden Veränderungen. Abstract by W. Winkler in Z. ges. Getreidew. 23(9): 185-186 (1936).]

Loska, Stephen. 401

Modern Wheat Conditioning Versus Wheat Tempering. (Abstract) Northwest. Miller 208, Sect. 2: 9a-10a, 17a-18a, 20a (Nov. 12, 1941).

Luby, Frank, Jr. 402

Humidity and Tempering Problems. Mod. Miller 51(20): 20 (May 17, 1924).

Lucke, Franz. 403

[Progress in the Conditioning of Wheat.] Fortschritte in der Weizen-Vorbereitung. Mühle 73(30): 955-957 (July 24, 1936).

M., E. 404

[Principles of the Grain Conditioner. What Effect does the Wheat Conditioner Have on Domestic Grain?] Grundsätzliches vom Getreidevorbereiter. Welchen Effekt hat der Weizenvorbereiter bei Inlandsgetreide? Mühle 69(29): 746 (July 21, 1932).

McCluggage, M. E. 405

Determination of Moisture Requirements for Tempering Wheat for Experimental Milling. Assoc. Oper. Millers Bul., pp. 962-963 (June 1939).

________ 406

A Review of the Literature on Wheat Conditioning. Assoc. Oper. Millers Bul., pp. 1,026-1,030 (May 1940). [Also in Amer. Miller 68(6): 34, 37, 40, 85-87 (June 1940); and in 40, v. 2., pp. 226-241.]

________ 407

Visit to Gral Mitre Mill in Buenos Aires. In Swiss Movement. Amer. Miller 75(9): 25 (Sept. 1947).

McCormick, R. E. 408

Effects of Length of Tempering Period on the Processes of Milling. [Unpublished master's thesis. Kansas State College, Manhattan.] (1930).

McKee, H. B. 409

Revising a Wheat Tempering System. Amer. Miller 67(2): 24-25 (Feb. 1939).

Madgwick, W. G. [C.] 410

The Effect on the Milling Process of Varying Vapor Pressure. Amer. Miller 71(7): 36, 38-40 (July 1943). [Abstract in Northwest. Miller 215(2), Sect. 2: 19a (July 14, 1943).]

Madgwick, W. C. 411

An Australian Flowsheet. Some Observations on Milling Technique. Amer. Miller 73(6): 38-40 (June 1945).

Maksimov, G. A. 412*

[Heat and Moisture Exchange in Seeds of Plants During Swelling--Experiments with Wheat.] Fiziol. Rast. 2: 81-83 (Jan./Feb. 1955). [In Russian. English title from Bibliography Agr. 19(11): 94,006 (1955).]

Mambish, I. E., and Demidov, A. R. 413

[Preparation of Grain for Milling.] Vorbereitung des Kornes zur Vermahlung und Kontrolle, pp. 16-26. In German. Translation of their [Control of the technological processes in grain milling (methods and apparatus).] Staatlicher Verlag für technische und ökonomische Literatur, Moscow (1953) [In Russian]. Translation by Alexander Ander, Kontrolle des technologischen Prozesses in Getreidemühlen (Methoden und Gerätschaften). Fachbuchverlag, Leipzig (1955).

________ and Demidov A. R. 414

[Table 24. Technical Coefficients of Conditioning and Milling Wheat to Three Kinds of Flour with a Yield of 20 + 30 + 28%.] Tabelle 24. Technologische Kennziffern der Vorbereitung und Vermahlung von Weizen zu drei Sorten Mehl mit einer Ausbeute von 20 + 30 + 28%. Ibid., pp. 68-73.

Marcos Gonzalez, Ramon. 415

[Synthetic Theories.] Teorias sintéticas. Tolva 9: 790-792 (Sept. 1951). [Also in Ceres [Valladolid, Spain] 16: 41, 43 (Nov. 1, 1951).]

________ 416

[Something About the Cells.] Algo sobre las células. Ceres [Valladolid, Spain] 19 (216): 19, 21 (June 1, 1954).

Markley, M. C. 417

Certain Effects of Varying the Hydrogen Ion Concentration of the Tempering Water upon the Wheat Proteins. Cereal Chem. 7(2): 154-161 (Mar. 1930).

Medel. 418

[Actual Problems in the Milling of Moist, Sprouted, or Otherwise Damaged Mill Stock of this Year's Harvest.] Aktuelle Fragen der Vermahlung feuchten, auswuchshaltigen oder anders geschädigten Mahlgetreides der diesjährigen Ernte. Mühle 91(40): 507 (Oct. 7, 1954).

Meller. 419

[Damping of Grain.] Vom Netzen des Getreides. Mühle 70(47): 1,242-1,243 (Nov. 23, 1933).

Miag. 420

[The Miller's Handbook.] Handbuch des Müllers. (German and English texts.) Ed. 9. Amme, Luther, Seck, Braunschweig (1936).

________ 421

[Wheat Conditioning. A Collection of Essays.] Die Weizenvorbereitung. Eine Aufsatzsammlung. [Articles and lectures from the years 1927-1952.] Ed. 5. Braunschweig (Dec. 1952).

Michelli, R. 422

[The Conditioning of Wheat in the Laboratory.] Le conditionnement des froments au laboratoire. Rev. des Fermentations et des Indus. Aliment. 6(4): 116-123 (1951).

Miller, B. S., and Johnson, J. A. 423

A Review of Methods for Determining the Quality of Wheat and Flour for Breadmaking. Kansas Agr. Expt. Sta. Tech. Bul. No. 76, 62 pp. (1954).

Miller, E. S. 424*
Milling Studies. Chicago (1920). [Through 142.]

———— 425*
Wheat Tempering. Amer. Miller 49(7): 724 (1921). [Through 406. Also in Oper. Miller 26: 202-204 (1921).]

———— 426*
Observations on Milling. Natl. Miller, Chicago (1923). [Through 406.]

———— 427
Short Time Wheat Conditioning. Northwest. Miller 155: 443-444 (Aug. 1, 1928). [Also in Mühle 65(36): (1928).]

———— 428*
Milling Studies. Natl. Miller, Chicago (1928). [Through 406.]

———— 429*
Sweating and the Conditioning of Wheat. Northwest. Miller 161: 103 (1930). [Through index to v. 161.]

———— 430
Penetration vs. Permeation. Natl. Miller and Amer. Miller 59(5): 19-20, 47 (1931).

———— 431
The Physical Aspects of Wheat Conditioning. An Examination of the Phenomena Attending Rapid Diffusion of Moisture in Grain in the Light of Present-Day Knowledge of Vapor Pressures and Heat Metamorphosis. Northwest. Miller 180(1): 17-18 (Oct. 10, 1934).

———— 432*
Conditioning. Northwest. Miller 180: 487 (1934). [Through index to vol. 180.]

———— 433
"Wet-Heat" Conditioning. Assoc. Oper. Millers Bul., pp. 750-751 (Nov. 1936). [Also in Northwest. Miller 188: 167 (1936).]

———— 434*
How Moisture Penetrates the Wheat Berry. Northwest. Miller 196: 30 (Nov. 9, 1938). [Through index to vol. 196.]

———— 435
Recent Developments in Wheat Conditioning. Northwest. Miller 198(4), Sect. 2: 2a-3a, 19a (May 10, 1939). [Also in Assoc. Oper. Millers Bul., pp. 944-946 (1939).]

———— 436*
The Use of Air in Milling. Northwest. Miller 201, Sect. 2: 3a (Mar. 13, 1940). [Through index to vol. 201.]

———— 437*
Hot Wheat Conditioning. Northwest. Miller 203, Sect. 2: 5a (Sept. 11, 1940). [Through index to vol. 203.]

———— 438
Studies in Practical Milling. Miller Pub. Co., Minneapolis (1941).

———— 439
Where Do We Go from Here? Amer. Miller 73(7): 39-42, 76-77 (July 1945).

———— 440
"Conditioning"--What? Why? When? Amer. Miller 75(11): 42, 46, 48, 50, 52 (Nov. 1947).

———— 441
The Physics of Wheat Conditioning. [Reprinted from Millers' Review and Dixie Miller (1926).] Northwest. Miller 256(2), Sect. 2: 5a-9a (July 10, 1956). [Also in Milling Prod. 21(7): 7-11 (July 1956).]

Milner, Max, and Shellenberger, J. A. 442

Physical Properties of Weathered Wheat in Relation to Internal Fissuring Detected Radiographically. Cereal Chem. 30(3): 202-212 (May 1953).

Mohs, K. 443

The Size of the Pores in Baked Bread. [Translated from Z. ges. Getreidew. 3(8): 17-26 (1912) by Charles G. Ferrari.] Cereal Chem. 1(3): 149-151 (May 1924).

________ 444

[Influence of Heat on Gluten Properties and Baking Quality of Wheat. Part II.] Über die Einwirkung der Wärme auf die Kleberbeschaffenheit und Backfähigkeit des Weizens. II. Teil. Z. ges. Getreidew. 25(5): 86-94 (1938).

________ and Klemt, G. 445

[Influence of Heat on Gluten Properties and Baking Quality of Wheat.] Ueber die Einwirkung der Wärme auf die Kleberbeschaffenheit und Backfähigkeit des Weizens. Z. ges. Getreide-, Mühlen- u. Bäckereiw. 24(12): 267-274 (1937).

Molinari, C. 446

[The Conditioning of Grain for Milling. Conclusion.] Die Vorbereitung des Getreides zur Vermahlung. Schluss. [Translated from Tech. Meun. 60: 3-6 (Jan/Feb. 1957).] Müllerei 10 (42): 77-78 (1957).

Molenarius. 447

[The Physical Behavior of the Wheat Kernel in Drying and Conditioning.] Das physikalische Verhalten des Weizenkornes beim Trocknen und Konditionieren. Z. ges. Getreide- u. Mühlenw. 20(5): 123-128 (May 1933).

Moor, C. R. 448

Applying European Milling Principles, Machines to American Mills May Give Improved Performance. Northwest. Miller 256(2), Sect. 2: 1a, 18a-22a (July 10, 1956); Milling Prod. 21(7): 1, 20-24 (July 1956).

Moote, Irene. 449

The Effect of Moisture on the Thermal Properties of Wheat. Canad. Jour. Technol. 31(2/3): 57-59 (Feb./Mar. 1953).

Moran, Thomas. 450

Chemistry of Wheat. Northwest. Miller 258(15), Sect. 2: 14a-18a (Oct. 8, 1957).

Mozzone, G. 451

[Calculation of Milling Results and Moisture.] Calcolo dei risultati di macinazione e umidità. Selezione di Tec. Molitoria 7(5): 91-95 (May 1956).

Mueller, Gerhard. 452

[Conditioning of Wheat and Aging of Flour.] Konditionierung und Mehllagerung. Mühle 70(45): 1,179-1,180 (Nov. 9, 1933).

________ 453

[Value and Technique of Test Conditioning.] Wert und Technik der Versuchskonditionierung. Mühle 75(22): 611-612 (June 3, 1938).

Mueller, H. F. 454

Wheat Tempering Progress. Natl. Miller 34(11): 16-17 (Nov. 1929).

Neitzert, Kurt. 455

[The Importance of Distribution of Moisture During Conditioning. Practical Experience in Operational Control in Domestic and Foreign Plants.] Die Bedeutung der Feuchtigkeitsverteilung bei der Konditionierung. Praktische Erfahrungen bei Betriebskontrollen in in- und ausländischen Betrieben. [Abstract *in* Diskussionstagung des Forschungsinstituts für Getreidechemie. Deut. Müller-Ztg. 49(5): 122 (Mar. 7, 1951). Also with title "Apparatur zur Kontrolle der Vorbereitung," *in* Zweite Jugenheimer Diskussionstagung. Mühle 88(9): 139 (Mar. 1, 1951).]

Neitzert, Kurt. 456

[Actual Problems in Technical Plant Control.] Aktuelle Probleme der technischen Betriebsführung. [Abstract in Diskussionstagung des Forschungsinstitutes für Getreidechemie. Deut. Müller-Ztg. 49(20): 513-514 (Oct. 1951).]

________ 457

[Influence of Storage, Drying, Tempering and Conditioning on the Milling Qualities of Bread Grain.] Beeinflussung der Mahlfähigkeit von Brotgetreide durch Lagerung, Trocknung, Abstehen und Konditionierung. [Abstract in Die 3. Jugenheimer Diskussionstagung. Mühle 89(11): 162-163 (Mar. 13, 1952). Also in Deut. Müller-Ztg. 50: 123-124 (Mar. 19, 1952).]

________ 458

[The Importance of Conditioning in Milling.] Die Bedeutung der Vorbereitung in der praktischen Müllerei. Mühle 89(17): 255-256 (Apr. 24, 1952).

________ 459

[The Control of the Grain Conditioning Process.] Die Kontrolle der Getreidevorbereitung. Müllerei 5(28): 45-46 (July 12, 1952). [Also in Mühle 89(27): 441-442 (July 3, 1952).]

________ 460*

[The Control of the Grain Conditioning Process.] Die Kontrolle der Getreidevorbereitung. Müllerei 8: 45-46 (Apr. 26, 1955). Reference and translation through G. M. Grosh.

________ 461

[Time and Temperature Factors in Grain Conditioning.] Zeit- und Temperaturfaktor bei der Getreidevorbereitung; and [Cold Conditioning of Wheat for Better Millability.] Kaltvorbereitung des Weizens zur Mahlfähigkeitsverbesserung. [Abstract in Die 6. Jugenheimer Diskussionstagung. Mühle 92(15): 180 (Mar. 25, 1955).]

________ 462

[Steam Conditioning of Grain.] Dampfbehandlung vom Getreide. [Abstract in Die 7. Jugenheimer Diskussionstagung. Mühle 93(14): 196-197 (Apr. 5, 1956). Also in Deut. Müller-Ztg. 54: 174 (Apr. 11, 1956).]

Neumann. 463

[What Temperatures Are Safe for Drying Grain?] Wie warm darf Heizluft beim Getreidetrocknen sein? Mühle 66(52): 1,610-1,611 (1929).

________ and Pelshenke. 464

[Bread Grain and Bread.] Brotgetreide und Brot. Ed. 5. Revised by P. F. Pelshenke, Paul Parey, Berlin (1954).

Nordstrom, Ken. 465

European Milling. Amer. Miller 82(8): 26 (Aug. 1954).

Nuret, H. 466

[Concerning the Absorption of Water by Grain.] Über die Wasseraufnahme von Getreide. Z. ges. Mühlenw. 6(12): 193-197 (Mar. 1930).

________ 467

[Diagrams on Wheat Conditioning. A Study of the Holding Period of Several Wheats.] Diagrammes de nettoyage. Étude du temps de repos dans le cas de plusieurs blés. Bul. Anciens Élèves École Franç. Meun. No. 152: 65-71 (Mar./Apr. 1956).

Ofner, F. R. 468

The Wheat Washer Problems and Solutions. Assoc. Oper. Millers Bul., pp. 2,238-2,243 (Apr. 1956).

Onishchenko, E. G., and Popadich, I. A. 469*

[Improvement of Bread-Baking Properties of Wheat Grain by Means of Hydrothermic Treatment and Methods of Determination of its Amylolytic Activity.] Biokhim. Zerna. Sbornik No. 3: 126-144 (1956). [In Russian, English title from Chem. Abs. 51: 9,025b (1957).]

Owen, P. C. 470
The Relation of Water Absorption by Wheat Seeds to Water Potential. Jour. Expt. Botany 3(9): 276-290 (Sept. 1952).

Oxley, T. A. 471
Study of the Water Content of Single Kernels of Wheat. Cereal Chem. 25(2): 111-127 (Mar. 1948).

________ 472
The Movement of Heat and Water in Stored Grains. Amer. Assoc. Cereal Chem. Trans. 6(2): 84-100 (Aug. 1948).

P., W. 473
[Wheat Conditioning.] Weizenvorbereitung. Mühle 70(6): 131-132 (Feb. 9, 1933).

Pap, Lajos. 474
[Hygroscopicity of Wheat.] A búza higroszkópossága. Mezőgazdasági Kutatások 3: 349-354 (Sept. 1930). [In Hungarian. German summary. For English compilation see 541.]

Pap, Lewis. 475
Hygroscopicity of Wheat. Cereal Chem. 8(3): 200-206 (May 1931).

Parker, T. S. 476
The Stabilisor and its Effects on Milling. Milling (Liverpool), 8pp. (Feb. 12, 1949).

Parkinson, J. M. 477*
Turkish Bath System. Milling (Liverpool) (June 16, 1928). [Quoted in 633.]

Parks, C. M. 478*
Theory of Wheat Cleaning and Conditioning. Assoc. Oper. Millers Bul., pp. 267-269 (1928). [Also in Amer. Miller 56(7): 756-758 (1928); Northwest. Miller 154: 1,054 (1928); and Mühle 65(29): (1928).]

________ 479
Theory of Modern Wheat Cleaning and Conditioning. A Paper Read at 33rd Annual Convention of AOM at Minneapolis, June 7, 1928. Northwest. Miller Prod. Ann. Sup. 192: 35-36 (Oct. 13, 1937).

Partridge, C. W. 480
Between the Elevator and the Mill. Assoc. Oper. Millers Bul., pp. 617-618 (Mar. 1935).

Pelshenke, P. F. 481
[The Optimal Moisture Content of Bread Grain Before the First Break.] Über den optimalen Wassergehalt des Brotgetreides vor dem ersten Schrot. Getreide u. Mehl 1(1): 1-2 (Jan. 1951).

________ 482
[New Facts and Experiments on the Structure and Composition of the Grain Kernel.] Neuere Ergebnisse und Erfahrungen über den Aufbau und die Zusammensetzung des Getreidekornes. Getreide u. Mehl 1(6): 45-50 (June 1951).

________ 483
[The Effect of a Short Heat Treatment on the Enzymatic Activity in Wheat.] Wirkung einer kurzen Hitzebehandlung auf die Enzymaktivität von Weizen. Getreide u. Mehl 2: 39-40 (Apr. 1952).

________ 484
[The Specific Heat of Wheat.] Die spezifische Wärme des Weizens. Getreide u. Mehl 5(4/5): 34-35 (Apr./May 1955). [See 560.]

________ 485
[The Behavior of the Wheat Kernel During Conditioning.] Über das Verhalten des Weizenkornes bei der Konditionierung. Ibid., 35-36. [See 556.]

Pelshenke, P. F. 486
[Temperatures in the Crushing Gap.] Temperaturen im Mahlspalt. Ibid., 37-38.

________ and Schäfer, W. 487
[Milling and Baking Research with Manitoba 5 Wheat.] Mahl- und Bachversuche mit Manitoba-Weizen 5. Mühle 89(30): 483-484; (51/52): 775-776 (July 24-Dec. 25, 1952).

________, Schäfer, W., and Tschiersch, G. 488
[The Effect of Moisture, Standing Time, Roll Differential and Flute Arrangement on the Processes at the First Break.] Der Einfluss von Feuchtigkeit, Abstehzeit, Voreilung und Riffelstellung auf die Vorgänge am I. Schrot. Mühle 94(45): 590-596 (Nov. 7, 1957).

Pence, R. O. 489
Physical Changes in Wheat During Tempering. Assoc. Oper. Millers Bul., pp. 906-907 (Aug. 1938). [Also in 40, v. 2, pp. 129-134; and Milling (Liverpool) 91: 269-270 (Aug. 27, 1938).]

________ 490
Wheat Conditioning. Assoc. Oper. Millers Bul., pp. 1,544-1,548 (Sept. 1946).

________ and Swanson, C. O. 491
Rate of Water Penetration in Wheat During Tempering. In 16, v. 1, pp. 110-119 (1920 to 1937). [Also in Assoc. Oper. Millers Bul., pp. 316-320 (1930).]

________ and Swanson, C. O. 492
Tempering Factors Affecting the Quantity and Quality of Wheat Flour. Kans. Agr. Expt. Sta. Bien. Rpt. 6, pp. 49-50 (1932).

Penndorf. 493
[The Laboratory Conditioner and Its Tasks.] Der Laboratoriums-Vorbereiter und seine Aufgaben. In 420, pp. 100-106 (1936). Shortened version in 421, pp. 125-127 (1952).

Penndorf, Fritz. 494
[The Influence of the Shape of the Radiators on the Performance of Grain Dryers and Conditioners.] Der Einfluss der Radiatorenform auf die Wirkungsweise der Getreide-Vorbereiter und -Trockner. [In 421, pp. 48-52.] From Mühle 88(4): 55-57 (Jan. 25, 1951).

Peresechnyĭ, P. P. 495†
[In Regard to the Theory of Grain Treatment with Water in Preparation for Milling.] Vsesoi͡uzn. Nauch.-Issled. Inst. Zerna i Prod. Ego Pererabotki Trudy 22: 151-168 (1951). [In Russian, English title from Bibliography Agr. 17(2): 18,743 (1953).]

Peternel, S. (Yugoslavia). 496
[Conditioning of Various Wheats.] Über das Konditionieren der Weizen. Mühle 66(12): 360-361 (1929).

Pfalzner, P. M. 497
The Specific Heat of Wheat. Canad. Jour. Technol. 29(5): 261-268 (1951).

Pfeuffer, Franz. 498
[Conditioning of Dry Wheat, the American Kinds in Particular, in Small Mills.] Die Vorbereitung von trockenem, insbesondere amerikanischem Weizen in Kleinmühlen. Mühlen-Ztg. 2(1): 4 (Jan. 3, 1948).

________ 499
[Important Questions for the Miller.] Wichtige, aktuelle Fragen für den Müller. Deut. Müller-Ztg. 48(7): 182-184 (Apr. 5, 1950).

________ 500
[Moisture Exchange in Milling Stock.] Der Feuchtigkeitausgleich im Mahlgetreide. Deut. Müller-Ztg. 50: 664-666 (Dec. 13, 1951).

Pfeuffer, Franz. 501

[Moisture Conditioning in Medium-Sized and Small Mills.] Feuchtigkeits-Vorbereitung in Mittel- und Kleinmühlen. Deut. Müller-Ztg. 51: 630 (Dec. 23, 1953).

Pfister. 502

[Some Observations on Conditioning of Wheat.] Einige Beobachtungen bei der Weizenvorbereitung. Mühle 66(18): 539-540 (May 2, 1929).

———— 503

[The Significance of Temperature for Milling.] Die Bedeutung der Temperatur für die Vermahlung. Mühle 92(51): 689 (Dec. 22, 1955).

Polewka, Ed. 504

[Duct Drier Used for Preparation of Wheat.] Schachttrockner als Weizenzurichter. Mühle 66(15): 447-448 (1929).

———— 505

[Conditioning of Grain--an Urgent Question of Today.] Das Vorbereiten des Getreides--eine dringende Tagesfrage. Mühle 67(32): 885-886 (Aug. 7, 1930).

———— 506

[Conditioning of Mixtures of Grain. Can Hard and Soft Wheats be Processed as a Mixture or Must They Be Separated According to Kind?] Vorbereitung von Getreidemischungen. Können Mischungen aus Hart- und Weichweizen gemeinschaftlich oder müssen sie nach Sorten getrennt verarbeitet werden? Mühle 67(38): (Sept. 18, 1930).

———— 507

[The New Crop and Grain Conditioning.] Die neue Ernte und die Getreidevorbereitung. Mühle 68(38): 385-386 (Sept. 17, 1931).

———— 508

[Hot Air or Radiator Conditioner?] Warmluft- und Radiatoren-Vorbereiter. Mühle 68(40): 1,107-1,109 (Oct. 1, 1931).

———— 509

[Theory and Practice in Grain Conditioning.] Theorie und Praxis in der Getreidevorbereitung. Mühle 69(24): 614-615 (June 16, 1932).

———— 510

[Conditioning of Grain.] Das Vorbereiten des Getreides. Mühle 70(22): 549-552 (June 1, 1933).

———— 511

[Drying, a Prerequisite for the Conditioning of Domestic Wheat.] Trocknung eine unerlässliche Vorbedingung für Vorbereitung von Inlandsweizen. Mühle 70(45): 1,179-1,182 (Nov. 9, 1933).

Pöllmann, Carl. 512

[The damping of Grain.] La bagnatura del grano. Selezione di Tec. Molitoria 6(8): 51-53 (Aug. 1955).

Prochazka, Franz. 513

[Practical Experience in the Conditioning of Wheat and Rye.] Einige praktische Erfahrungen in der Vorbereitung von Weizen und Roggen. Mühle 75(22): 599-602 (June 3, 1938).

Procopio, Mario. 514

[New Process for Conditioning Grain.] Nuovo procedimento per il condizionamento del grano. Ital. e i Cereali 6: 537-538 (Oct. 1951).

Pti͡tsyn, S. D. 515†

[Permissible Heating of Wheat Kernels.] Doklady Vsesoyuz. Akad. Sel'skokhoz. Nauk im V. I. Lenina 15(8): 45-48 (1950). [In Russian, English title from Bibliography Agr. 15: 8,411 (1951).]

Pusch, T. C. 516
Cleaning Hard Winter Wheat for the Production of White Flour. Amer. Miller 79(4): 26-28, 31, 86-88 (Apr. 1951).

Rada, I. T. 517†
[The Preparatory Processing.] Az elökészitö megmunkálás. In his [Technology of Flour Milling] Örlő és hantoloiparok, pp. 280-291. Tankonyvkiado, Budapest, Hungary (1955).

——— 518
[Results of Physical Studies of Flour and Dough with the Neo-Laborograph.] Versuchsergebnisse mechanischer Untersuchungen von Mehl und Teig mit dem Neo-Laborograph. Getreide u. Mehl 5(12): 92-95 (Dec. 1955).

Ranney, J. I. 519
Tempering--Based on Extractions. Natl. Miller 31(3): 36,65 (Mar. 1926).

Reimann. 520
[The Water Absorption of Wheat During Conditioning. (A Scientific Investigation in an American Experimental Mill).] Die Wasseraufnahmefähigkeit des Weizens bei der Vorbereitung. (Eine wissenschaftliche Untersuchung in einer amerikanischen Versuchsmühle.) [Abstract of 626.] Mühle 67(27): 749-751 (July 3, 1930).

Reimann, Erich. 521
[New Grain Drier and Conditioner.] Neuer Getreide-Trockner und -Vorbereiter. Mühle 93(24): 337-338 (June 14, 1956).

Remington, J. S. 522*
Science and the Miller. Northern Publishing Co., Liverpool (1914). [Through 393.]

——— 523
The Conditioning of Wheat. Indus. Chem. 2: 203-207 (May 1926).

Rich, C. E. 524
Some Problems Associated with Wheat Conditioning. Assoc. Oper. Millers Bul., pp. 1,802-1,806 (Mar. 1950). [Abstract in Amer. Miller 77(6): 42 (June 1949); Miller (London) 81 (3,730): 945-947 (Aug. 7, 1950); and Northwest. Miller 238(11): 20a-21a (June 14, 1949).]

Ritter, Kurt. 525
[Enzymes and Conditioning.] Enzyme und Konditionierung. Mühlenlaboratorium 8(6): 73-88 (June 1938). [Similar subject, no title, in Z. ges. Getreidew. 25(6): 118-120 (1938).]

——— 526
[New Views on the Distribution, Amount, and Kind of Enzymes in Cereal Grain Kernels.] Neuere Anschauungen über Verteilung, Menge und Art der Enzyme im Getreidekorn. Getreide, Mehl u. Brot 4(15/16): 165-170 (Aug. 1950).

Robinson, C. E. 527
Wheat Cleaning and Conditioning. Assoc. Oper. Millers Bul., pp. 307-308 (1926). [Also in Amer. Miller 54 (7): 745 (1926); and Natl. Miller 31(7): 39 (1926).]

Robinson, F. B. 528
Wheat Tempering Experiments. Northwest. Miller 230(2), Sect. 2: 1a, 8a, 10a, (Apr. 8, 1947); Milling Prod. 12(4): 1 (1947).

Robinson, Thomas, and Son, Ltd. 529
Conditioning. A Practical Treatise on the Scientific Preparation of Wheat Before Grinding. 20 pp. Rochdale, England (Nov. 1930).

——— 530
Talking of Drying ... no. 1 and no. 2. Milling (Liverpool) 106: (Jan. 5-12, 1946).

——— 531
The Case for Hot Conditioning. 14 pp. Rochdale, England [1955?].

Roch, Eugen. 532
[Wheat Conditioning.] Weizenvorbereitung. Mühle 66(38): 1,189-1,190 (1929).

Rohrlich, M. 533
[Influence of the Drying of Wheat on the Enzyme Activity and Gluten Protein.] Einfluss der Trocknung des Weizens auf Fermentaktivität und Klebereiweiss. [Abstract in Mühle 92(24): 320 (June 16, 1955).] From Internatl. Bread Cong. [Proc.] 3: 193-197 (1955).

________ and Brückner, G. 534
[Influence of Drying of Wheat on Enzyme Activity, Gluten Protein and Capacity for Water Absorption.] Einfluss der Trocknung des Weizens auf Fermentaktivität, Klebereiweiss und Wasseraufnahmefähigkeit. Mühle 93(2): 13-15; (3): 28-29 (Jan. 12-19, 1956).

________ and Brückner, G. 535
[Flour Production.] Mehlherstellung. [Conditioning.] Konditionierung. In their Das Getreide I Teil: Das Getreide und Seine Verarbeitung. Grundlagen und Fortschritte der Lebensmitteluntersuchung, v. 4, pp. 84-90 and 151-156. Hayn, Berlin (1956).

Rossner, H. 536
[Combined Warm Water and Warm Air Conditioner.] Kombinierter Warmwasser- u. Luftvorbereiter. Mühle 70(22): 549-550 (June 1, 1933).

Rossner, Hermann. 537
A German 300-bbl. Flour Mill. Northwest. Miller Prod. Ann. Sup. 188: 45-50 (Oct. 21, 1936).

Roth, Ernest. 538
Cleaning, Tempering and Conditioning of Wheat. Assoc. Oper. Millers Bul., pp. 2,247-2,250 (May 1956). [Abstract in Northwest. Miller 253(24), Sect. 2: 6a (June 14, 1955).]

Roth, E., and Dumermuth, R. 539
[Vacuum Apparatus as Conditioner.] Vakuumapparat als Vorbereiter. Mühle 89(49): 762 (Dec. 4, 1952).

Rowe, W. F., Dybevick, E. S., and Mattson, David. 540
What Wheat Conditioning Research Does the Operative Miller Want? Assoc. Oper. Millers Bul., p. 2,378 (Apr. 1958).

Rozsa, Tibor. 541
Drinking Habits of the Wheat Berry. [Summary of 474.] Northwest. Miller Prod. Ann. Sup. 184: 73-74 (Oct. 16, 1935).

Ruemele, Th. 542
[Problems in Dampening of Bread Grain.] Benetzungsfragen des Brotgetreides. Ztschr. f. Untersuch. der Lebensmtl. 71(5): 411-415 (May 1936).

Rumpf, Saladin. 543
[Concerning the Infrared Treatment of Grain.] Über die Infrarotbehandlung von Getreide. [Abstract in Die 6. Jugenheimer Diskussionstagung. Mühle 92(13): 145-146 (Mar. 31, 1955).]

________ 544
[Experiences with Treatment of Grain by Radiant Heat.] Erfahrungen mit der Getreidebehandlung durch Strahlungswärme. Mühle 92(18): 221-222 (May 5, 1955).

________ and Kipper, W. 545
[Improvement of the Baking Quality by Treatment with Infrared Radiation, Especially for Sprout Damage.] Die Verbesserung der Backfähigkeit, besonders bei Auswuchsschäden, durch Infrarotbestrahlung. Mühle 92(1): 1 (Jan. 6, 1955).

________ and Linder, H. 546
[Infrared in the Mill.] Infrarot in der Mühle. Mühle 90(18): 243-244 (Apr. 30, 1953).

Rutherford, Adrian. 547

Grain Conditioning in England. [Abstract in Conditioning, Grain Cleaning, Fumigating. Amer. Miller 86(1): 25 (Jan. 1958).]

Sánchez Bueno, R. J. 548

[Conditioning of Wheat, Ambient Heat and Humidity.] Acondicionado del trigo, calor y humedad ambiente. Ceres (Spain) 4(40): 37 (Oct. 1, 1939).

Sandstedt, R. M. 549

Disintegration of the Wheat Kernel During Milling. Sixteen mm. sound film, University of Nebraska Film Library, Lincoln. Described in Mühle 93(45): 667 (Nov. 8, 1956).

Sch., T. 550

[Process for Conditioning or Treatment of Wheat for Milling. Patent Application of the Research Association of British Flour Millers, St. Albans, Hertford, England, p. 32076 III/50a.] Verfahren zur Konditionierung oder Behandlung von Weizen vor der Vermahlung. Patentanmeldung der Research Association of British Flour Millers, St. Albans, Hertford, England, p. 32076 III/50a. Mühle 88(4): 49 (Jan. 25, 1951).

Schäfer, W. 551

[Investigations Concerning the Absorption of Water by Kernels of Cereal Grains.] Untersuchungen über die Wasseraufnahme des Getreidekornes. Getreide, Mehl u. Brot 4(17/18): 192-197 (1950).

———— 552

[Water Absorption of the Cereal Grain Kernel.] Die Wasseraufnahme des Getreidekornes. Mühle 88(4): 46-49 (Jan. 25, 1951).

———— 553

[Milling and the Structure of Wheat.] Müllerei und Weizenbau. Mühle 88(51/52): 830-832 (Dec. 20, 1951).

———— 554

[Research on Steam Treatment of Wheat.] Untersuchungen über die Dampfbehandlung von Weizen. Müllerei 5(28): 47-50 (July 12, 1952). [Also in Mühle 89(27): 442-445 (July 3, 1952).]

———— 555*

[The Behavior of the Wheat Kernel During Conditioning.] Über das Verhalten des Weizenkornes bei der Konditionierung. Dissertation TH Braunschweig (1953). [Through 313.]

———— 556

[The Behavior of the Wheat Kernel During Conditioning.] Über das Verhalten des Weizenkernes bei der Konditionierung. [Abstract of 555.] Cong. Internac. de Indus. Agr. Relac. de Comun. Presentadas 10(3): 2232-2237 (1954). [Similar presentation at Nordisk Cerealkemistförenings och Nordiskt Cerealistförbunds Kongress i Stockholm 1954. Abstract in Nordische Getreidechemikertagung in Stockholm. Mühle 91(26): 325 (July 1, 1954).]

———— 557

[The Effect of Conditioning on the Microscopic Picture.] Die Wirkung der Vorbereitung im mikroskopischen Bild. Mühle 91 (43): 558 (Oct. 28, 1954). [See 178.]

———— 558

[The Temperature on the Surface of the Cereal Grain Kernel.] Die Temperatur an der Oberfläche des Getreidekorns. Mühle 91(48): 631-632 (Dec. 2, 1954).

———— 559

[The Measurement of the Temperature Difference Between Kernel Surface and Kernel Interior.] Die Messung der Temperaturdifferenz zwischen Kornoberfläche und Korninnerem. Mühle 91(51): 674-675 (Dec. 23, 1954).

Schäfer, W. 560
[The Specific Heat of Wheat.] Die spezifische Wärme des Weizens. Mühle 92(20): 249-250; (21): 269-270; (22): 286-287 (May 19- June 2, 1955). [See 484.]

——— 561
Wheat Conditioning. (Abstract) Northwest. Miller 255(24), Sect. 2: 12a (June 12, 1956).

——— 562
[The Possibility of Improving the Flour Quality in Small and Medium Sized Mills After Prohibition of Bleach and Treatment Becomes Effective.] Möglichkeiten der Mehlqualitätsverbesserung für Klein- und Mittelmühlen nach dem Inkrafttreten des Bleich- und Behandlungsverbotes. [Excerpts from a report at Offenberg conference.] Mühle 94(13): 157-159 (Mar. 28, 1957).

——— 563
[Quality Flour Without Bromate.] Qualitätsmehle--auch ohne Bromatbehandlung. (Abstract) Mühle 94(48): 631 (Nov. 28, 1957).

Scheuch, Franz. 564
[Concerning Wet and Dry Cleaning Without a Conditioner.] Über die Trocken- und Nassreinigung ohne Vorbereiter. Deut. Müller-Ztg. 49(20): 501-503 (Oct. 3, 1951).

——— 565
[How Can a Good Flour Be Produced in the Small Mill?] Wie lässt sich auch in der Kleinmühle ein gutes Mehl herstellen? Mühle 89(1): 7; (2): 24 (Jan. 3-10, 1952).

——— 566
[On the Damping of Grain.] Vom Netzen des Getreides. Mühle 90 (33): 501 (Aug. 13, 1953).

——— 567
[Atomizing-Damping Before the First Break.] Die Vernebelungsnetzung vor dem ersten Schrot. Mühle 91(7): 80 (Feb. 18, 1954).

——— 568
[Influence of Cold on Milling and Baking Quality of Flour.] Einfluss der Kälte auf die Vermahlung und die Backfähigkeit der Mehle. Mühle 91(40): 512 (Oct. 7, 1954).

——— 569
[Storage Bins and Tempering Bins. An Important Factor in Obtaining Uniform Flour.] Silozellen und Abstehzellen. Ein wichtigen Faktor für gleichbleibendes Mehl. Mühle 93(33): 471-472 (Aug. 16, 1956).

Scheurich, J. J. 570
Soft Wheat Milling. Amer. Miller 50(7): 746-747 (July 1, 1922).

Schiele, K. 571
[Atomizing Damping Before the First Break.] Vernebelung vor dem ersten Schrot. Deut. Müller-Ztg. 53: 230 (May 18, 1955). [Also in Mühle 91(38): 475-476 (Sept. 23, 1954).]

Schiess, Fritz. 572
The Future Trend in Wheat Cleaning. Assoc. Oper. Millers Bul., pp. 2,367-2,368 (Feb. 1958).

Schmidt, E. A. 573
[Barge Mishap Furthered Agricultural Research. A Contribution to the Subject of Wheat Conditioning.] Schiffsunglück förderte landbauwissenschaftliche Forschung. Ein Beitrag zur Weizenvorbereitung. Z. ges. Getreidew. 25(8): 153-160 (1938).

Schmidt, H. 574
[Why Do We Steam (Condition) Grain for Milling?] Warum dämpfen (konditionieren) wir das Getreide vor der Vermahlung? Mühle 64(33): 1,030-1,031 (1927).

Schmucker, Joseph. 575
Development of Wheat Conditioning. [Translated from Mühle 70 (22): 543-544 (June 1, 1933) by Clinton L. Brooke.] Northwest. Miller 180(1), Sect. 2: 22 (Oct. 10, 1934).

Schnick, Robert. 576

[Hot Air or Radiator Conditioner?] Warmluft- oder Radiatorenvorbereiter? Mühle 68 (36): 1,002-1,003 (1931).

——— 577

[Wheat Conditioning.] Weizenvorbereitung. Mühle 70(3): 53-55 (Jan. 19, 1933).

——— 578

What Price Wheat Conditioning? [Translated from Mühle by Clinton L. Brooke.] Northwest. Miller 192: 44-45 (Dec. 8, 1937).

Schofield, T. 579

Aspects of the Development of Conditioning. Story of the Birth of Modern Improvements. Miller (London) 81(3,716): 527-530, 532 (Apr. 24, 1950). [Similar title in Milling (Liverpool) 114(16): 372-376 (Apr. 23, 1950).]

Scholz, Herbert. 580

[Prohibition of the Use of Bromate and Flour Quality.] Bromatverbot und Mehlqualität. Mühle 94(50): 651-652; 95(1): 1-2 (Dec. 12, 1957, Jan. 2, 1958).

Schreiner, Josef. 581

[Further Constructive Development of the Radiator Conditioner.] Die konstruktive Weiterentwicklung des Radiatoren-Vorbereiters. Müllerei 4(49): 782-784 (Dec. 8, 1951).

Schroeder, H. 581a

[The Selectively Permeable Covering of the Wheat Kernel.] Über die selektiv permeabele Hülle Weizenkornes. Flora 102: 186-208 (1911).

Schulz, E. 582

[The Conditioner, Research and Milling Practice.] Konditioneur, Forschung und Mühleneinsatz. Mühle 90(37): 559-560 (Sept. 10, 1953).

Schweitzer, F. 583

Conditioning--Yes or No? A Lecture Delivered at the 1953 Conference of German Millers. [Translation from Vorbereiten, ja oder nein? Mühle 90: 412-414 (July 9, 1953).] Milling (Liverpool) 121: 766-767, 771 (Dec. 19, 1953). [Also in Deutsche Müller-Ztg. 51(18): 429-431 (1953); and L und E 6(7): 4-6; (8): 8-9 (July, Aug. 1953).]

Scott, James. 584*

The Microscope in the Mill. Northern Publishing Co., Liverpool (1920). [Through 406.]

——— 585

Conditioning. Microscopical and Chemical Changes. 10 pp. [Reprinted from 584.] Henry Simon, Ltd., Manchester, England.

Scott, J. H. 586

The Behavior of Moisture in Wheat. Conditioning. In his Flour Milling Processes. Ed. 2, rev. Chapters 4 and 5. Chapman and Hall, London (1951).

Seeborg, E. F., and Barmore, M. A. 587

The Influence of Milling Moisture on Flour Yield, Flour Ash and Milling Behavior of Wheat. Northwest. Miller 248(2), Sect. 2: 1a, 14a-17a (July 8, 1952). [Also in Milling Prod. 17(7): 1, 16-19 (July 1952).]

Seidel, Kurt. 588

[Drying of Grain at Higher Temperatures.] Getreidetrocknung bei höherer Temperatur. Getreide u. Mehl 5(10): 76-78 (Oct. 1955). [Also in Internatl. Bread Cong. [Proc.] 3: 203-205 (1955). Similar title in Milling 127: 157-159 (Aug. 11, 1956); and Mühle 93(24): 320 (1956).]

Senti, F. R., and Maclay, W. D. 589

Wheat Utilization Research Program of the U. S. Department of Agriculture and Its Relation to the Operative Miller. Assoc. Oper. Millers Bul., pp. 2,264-2,270 (Aug. 1956). [Also in Southwest. Miller 35(15): 54-55 (June 12, 1956).]

Shellenberger, J. A. 590

Cracks in Bran Coat of Weathered Wheat Aid in Tempering. [Abstract in Northwest. Miller 247(20), Sect. 2: 8a (May 13, 1952). See 442.]

Shollenberger, J. H. 591
Moisture in Wheat and Mill Products. U. S. Dept. Agr. Bul. No. 788, 12 pp. (May 15, 1919).

——— 592
The Influence of Relative Humidity and Moisture Content of Wheat on Milling Yields and Moisture Content of Flour. U. S. Dept. Agr. Bul. No. 1,013, 12 pp. (Dec. 22, 1921).

Sickingen, Theo. 593
[Grain Kernel and Moisture.] Getreidekorn und Feuchtigkeit. Mühle 88(4): 59 (Jan. 25, 1951).

Simon, E. D. 594
The Principles of Wheat Conditioning. A Paper Read at the Convention of the National Association of British and Irish Millers, Buxton, 13th June, 1923. 16 pp. Simon, Manchester, England. [Also in Milling (Liverpool) 60(24): 738-740 (June 16, 1923).]

——— 595
Conditioning--Scientific data. Conditioning--the Practical Problem. In his The Physical Science of Flour Milling, pp. 87-118. Northern Publishing Co., Liverpool (1930).

Simon, Henry, Ltd. 596
Wheat Conditioning. Some Recent Developments. (Occasional letter) No. 168, 6 pp. Cheadle Heath, Stockport (Mar. 1939).

Simons, Johann. 597
[Grain Conditioning Apparatus. The Effect of Conditioning.] Getreide-Konditionierungsanlagen. Die Wirkung der Konditionierung. In his Neuzeitliche Müllerei-Maschinen. Mühle 65(49): 1,477-1,482 (Dec. 6, 1928).

Smeets, H., and Cleve, H. 598
Determination of Conditioning by Measuring Softness. [Translated from Müllerei 7(39): 505-507 (Sept. 25, 1954) by R. R. Vitols and R. E. Brown.] Milling Prod. 21(4): 5, 12, 13, 16 (Apr. 1956). [Also in Northwest. Miller 255(15), Sect. 2: 3a, 10a, 11a, 14a (Apr. 10, 1956).]

Smith, Leslie. 599
Objects of Conditioning. Conditioners and Dryers. In his Flour Milling Technology. Ed. 3, pp. 115-128. Northern Publishing Co., Liverpool (1944).

Soenen, M. 600*
[The Conditioning of Wheat.] Le conditionnement du froment. (1935). [Through 357.]

——— 601
[Grain Conditioning and the Degree of Fineness of Flour.] Getreide-Vorbereitung und Feinheitsgrad der Mehle. Deut. Müller-Ztg. 50(1): 12-13 (Jan. 9, 1952). [Also in Mühle 88(28): 450-451 (July 12, 1951).]

Sosedov, N. I., Shvetsova, V. A., Vakar, A. B., and Drozdova, Z. B. 602
Biochemical Processes in Wheat Conditioning. Acad. Sci. Bul. U.R.S.S., Ser. Biol (VII serie), pp. 873-879 (1939). [In Russian. English summary, p. 879].

——— Vakar, A. B., Shvetsova, V. A., and Drozdova, Z. B. 603*
[Biochemical Processes During Conditioning of Wheat, II.] Biokhimiya 7: 130-141 (1942). [In Russian. English title from Chem. Abs. 38: 172 (1944).]

Spehr, A. W. 604
Tempering Wheat for Milling. A paper delivered at the 28th Annual Convention of the AOM at Chicago, Ill., June 5, 1923. Northwest. Miller, Prod. Ann. Sup.: 33-34 (Oct. 13, 1937). [Also in Assoc. Oper. Millers Bul., p. 121 (1923).]

Speight, John. 605
Extraction of Air from Wheat Seen as Key to Successful Conditioning. Northwest. Miller 255(7), Sect. 2: 5a-7a (Feb. 14, 1956). [Also in Milling Prod. 21(2): 7-9 (Feb. 1956).]

Speight, John. 606
[Progress in Conditioning and the Control of Milling Through Science.] Fortschritte in der Konditionierung und der Vermahlungskontrolle durch die Wissenschaft. Mühle 93(40): 573-574 (Oct. 4, 1956).

Stanger, E. A. 607
Pointers to a Profitable Mill Construction. [Abstract in Northwest. Miller 256(16): 11, 26 (Oct. 16, 1956).]

Stark, Henry. 608
The Time of Tempering. Natl. Miller 30(12): 20 (Dec. 1925).

Stöckman, K. 609
[The Importance of the "Specific Heat" of Grain.] Die Bedeutung der "spezifischen Wärme" des Getreides. Mühle 88(4): 57-58 (Jan. 25, 1951).

Sugden, G. H. 610
Various Aspects of Wheat Conditioning. Beretning fra Nordisk Cerealkjemikerforenings Kongress i Bergen 1950, pp. 119-142. [Also in Miller (London) 81: 987-990, 1,003 (Aug. 21, 1950); Milling (Liverpool) 115(8): 194-200 (1950); and Cereal Sci. Today 1(4): 136-142 (Oct. 1956).]

——— 611
Warm Wheat Milling. Milling (Liverpool) 128: 94, 96, 98, 100, 110 (July 24, 1954). [Also in Nordische Getreidechemikertagung in Stockholm. Mühle 91 (26): 325-326 (July 1, 1954).]

Sullivan, B. 612
Quick Tempering of Wheat for Experimental Milling. Cereal Chem. 18(5): 695-696 (Sept. 1941).

Swafford, C. V. 613
Heat and Temperature. Assoc. Oper. Millers Bul., pp. 358-362 (Apr. 1931). [Also in 40, v. 1, pp. 137-144.]

Swanson, C. O. 614
Wheat Conditioning. Amer. Miller 41(6): 467-469 (June 1, 1913).

——— 615
What We Have Learned About Wheat Tempering. In 40, v. 1, pp. 203-210. [Also in Assoc. Oper. Millers Bul., pp. 485-487 (1933).]

——— 616
Wheat Conditioning or Tempering. In his Wheat and Flour Quality, pp. 132-134. Burgess, Minneapolis (1938).

——— 617
Effects of Water on Test Weight, Flour Yield and Other Properties of Wheat. In 40, v. 2, pp. 299-311.

——— 618
Adsorption of Liquid. Northwest. Miller 202, Sect. 2: 7a, 15a-16a (Apr. 10, 1940).

——— 619
How Water Tempers Wheat. Northwest. Miller 202, Sect. 2: 8a-9a (June 12, 1940).

——— 620
Effects of Moisture on the Physical and Other Properties of Wheat. Cereal Chem. 18(6): 705-729 (Nov. 1941).

——— 621
The Absorption of Water by Wheat. Northwest. Miller 211, Sect. 2: 11a-12a (July 8); Sect. 2: 12a-13a (Aug. 12, 1942).

Swanson, C. O. 622
Factors that Influence the Physical and Other Properties of Wheat. V. Effect of Frequent Rains Accompanied by Storms on Blackhull, Chiefkan, and Tenmarq. Cereal Chem. 21(2): 126-140 (Mar. 1944).

——— 623
Effect of Wetting Wheat Upon Its Structure. Northwest. Miller 225(11), Sect. 2: 12a-15a (Mar. 12, 1946).

——— Fitz, L. A., and Dunton, L. 624
The Milling and Baking Quality and Chemical Composition of Wheat and Flour as Influenced by: 1, Different Methods of Handling and Storing; 2, Heat and Moisture; 3, Germination. Kansas Agr. Expt. Sta. Tech. Bul. No. 1, 83 pp. (Jan. 10, 1916).

——— and Pence, R. O. 625
Moisture in Relation to Yield, Protein Percent, and Test Weight. In 40, v. 1, pp. 185-196.

——— and Pence, R. O. 626
The Penetration Rate of Water in Wheat During Tempering as Disclosed by College Mill Trials. Amer. Miller 58: 435-436 (May 1, 1930). [See 520.]

T., A. 627
[Wheat Conditioning. Equipment and Purpose.] Getreidevorbereitung. Einrichtung und Zweck. Mühle 69(15): 371 (Apr. 14, 1932).

Tague, E. L. 628
Changes Taking Place in the Tempering of Wheat. Jour. Agr. Res. 20(4): 271-275 (Nov. 15, 1920).

Talmadge, F. L. 629
What Influences Wheat Tempering? Natl. Miller 34(9): 16, 74 (Sept. 1929).

Tarutin, P. P. 630†
[A Speedy Process of Wheat Conditioning During Preparation of Grain for Milling.] Moscow. Vsesoi͡uzn. Nauch.-Issled. Inst. Zerna i Prod. Ego Pererabotki. Trudy 31: 5-24 (1956). [In Russian. English title from Bibliography Agr. 21(10): 89,382 (1957).]

Thomas, B. 631*
[Glassiness and Inner Grain Structure.] Glasigkeit und innere Kornausbildung. Mühlenlaboratorium 11: 57-64 (July 11, 1941). Mühle 78(28): (1941). [Through Chem. Abs. 38: $2,128^{2}$.]

Thomas, P. W. 632
The Modern Way of Wheat Conditioning. Amer. Miller 68(1): 122, 127-128 (Jan. 1940).

Thompson, W. S. 633
A Historical Study of Wheat Conditioning. National Joint Industrial Council for the Flour Milling Industry, Tech. Ed. Ser. Pamphlet No. 11, 43 pp. London (July 1934).

Tudor, W. C. 634*
[The Conditioning of Wheat by Heat Treatment.] Acondicionamiento de trigo por tratamiento a calor. Revista molinera de la R. argentina 2: 192-193 (1936). [Abstract in Anales Asoc. Quim. Arg. 26: 10B (1938). Through Chem. Abs. 32: 7,143 (1938).]

Ugrimoff, A. von. 635
[Some Investigations on the Entrance of Water into the Wheat Kernels.] Einige Versuche über das Eindringen des Wassers in Weizenkörner. Mühle 70(24): 603-604; (25): 625-627 (1933).

Ulrich, H. 636
[Equalization of Different Moisture Contents of Stored Grain.] Über die Angleichung unterschiedlicher Feuchtigkeiten des Lagergetreides. Müllerei 5(10): 159-160 (Mar. 8, 1952).

Vermeylen, Jos. 637
[A Contribution to the Study of Wheat Conditioning.] Contribution à l'étude du conditionnement des blés. IV. Cong. Internatl. Tech. Chim. Indus. Agr., Brussels 3: 503-524 (1935).

Vermeylen, J. 638
[A New Laboratory Conditioner.] Un nouveau conditionneur de laboratoire. Bul. École Meun. Belge 17(1): 1-5 (1955).

Verna, A. 639
[Heat Treatment of Grain. Measurement of Water and of Moisture.] Trattamento termico del grano. Misurazione dell'acqua e dell'umidità. Selezione di Tec. Molitoria 6(5): 62-63 (May 1955).

Vilm, Henry. 640
Wheat Tempering. Assoc. Oper. Millers Bul., p. 405 (Dec. 1931).

Voller, W. R. 641
Wheat Conditioning. In his Modern Flour Milling. Ed. 2, pp. 71-81. Bellows, Gloucester, England (1892).

W. 642
[Wheat Conditioning.] Weizenvorbereitung. Mühle 70(12): 284 (Mar. 23, 1933).

W., L. 643
[Grain Drier and Grain Conditioner in Small and Medium-Sized Mills.] Getreidetrockner und -vorbereiter in Klein- und Mittelmühlen. Mühle 93(23): 328 (June 7, 1956).

Wagner, Johann. 644
[Cereal Grain Drier, Conditioner and Prepurifier.] Getreidetrockner, -vorbereiter und -vorreiniger. Mühle 92(51): 694 (Dec. 22, 1955).

Walden, C. C., Gookins, O. E., and Brockington, S. F. 645
The Distribution of Potassium Bromate Added to Wheat in the Tempering Water. Amer. Assoc. Cereal Chem. Trans. 13(1): 59-62 (Feb. 1955).

Walter, H. 646
[The Moisture for Milling in the Small Mill.] Die Vermahlungsfeuchtigkeit in der Kleinmühle. Mühle 94(47): 621 (Nov. 21, 1957).

Ward, H. H. 647
Some Recent Developments in the Application of Heat in Wheat Conditioning. Being notes on a lecture delivered at Liverpool on April 1, 1936. 24 pp. The Aynsome Laboratories, Lancaster, England. [Also in Milling (Liverpool) 86(15): 407 (Apr. 11, 1936). Similar subject matter (abstract) in Improving English Wheat. Milling (Liverpool) (Jan. 23, 1937).]

Weber, Rud. 648
[Conditioning and Milling of Mixtures of Hard and Soft Wheat Without a Conditioner.] Vorbereitung und Vermahlung von Mischungen mit harten und weichen Weizen ohne Vorbereiter. Müllerei 4 (51/52): 811 (Dec. 22, 1951).

Werner, Kornel. 649
[Conditioning of Wheat Before Milling.] Die Vorbereitung des Weizens vor der Vermahlung. Mühle 68(10): 269-270; (11): 301-304 (Mar. 5, 12, 1931).

Wichser, F. W., and Shellenberger, J. A. 650
Relationship of Physical Factors to the Granulation of Flour. Northwest. Miller 238(11), Sect. 2: 1a, 26a-27a, 29a-30a (June 14, 1949).

Wiegand, K. H. 651
[Conditioning of Wheat in Small and Medium-Sized Mills.] Weizenvorbereitung in Klein- und Mittelmühlen. Deut. Müller-Ztg. 48(7): 181-182 (Apr. 5, 1950).

Wild, P. 652
[Conditioning of Soft Wheat and the Influence on Baking Quality.] Weichweizenvorbereitung und Beeinflussung der Backfähigkeit. Müllerei 3(32): 493-494 (Aug. 12, 1950).

Wilhelm, Arthur. 653
[Grain Conditioning in Small Mills.] Die Getreidevorbereitung in den Kleinmühlen. Müllerei 7(24): 309-310 (June 12, 1954).

——— 654
[Fundamentals of the Small and the Smallest Conditioner.] Grundlegendes über Klein- und Kleinstvorbereiter. Müllerei 8(7): 84-85 (Feb. 12, 1955). [Also with title "Considerazioni fondamentali sui piccoli condizionatori" in Selezione di Tec. Molitoria 7(4): 71-73 (Apr. 1956).]

Will. 655
[Washing and Conditioning in Small and Medium-Sized Mills.] Die Wäscherei und Vorbereitung in der Klein- und Mittelmühle. Deut. Müller-Ztg. 49(12): 307-308; (13): 334-335 (June 13, 27, 1951).

Williams, B. C. 656
Preparing Wheat for Milling Up to the First Break. Amer. Miller 47(7): 638-640 (July 1, 1919).

Williams, E. A. 657
Washing and Conditioning. In his Flour Mill Operation Under Present Conditions. A General Advancement in Technical Skill. Milling (Liverpool) 119: 686-688, 690-692, 694 (Dec. 20, 1952).

Wilson, J. 658
Some Aspects of Conditioning. Milling (Liverpool) 119: 682-683 (Dec. 20, 1952).

Witter, F. C. 659
What Is Research in the Mills? Assoc. Oper. Millers Bul., pp. 721-722 (June 1936).

Workman, H. M. 660
A Modern Wheat Washer and Conditioner. The Principles of Conditioning. Milling (Liverpool) 67: 531-532, 534 (Oct. 30, 1926).

X. 661
[Who Is Right?] Wer hat recht? Müllerei 7(49): 665-666 (Dec. 4, 1954).

X., A. 662
[The Conditioning of Grain--A Pressing Problem.] Das Vorbereiten des Getreides--eine dringende Tagesfrage. Mühle 68(44): 1,210-1,211 (Oct. 29, 1931).

——— 663
[Wheat Conditioning. Theory and Practice.--Conditioning of Foreign and Domestic Wheat.--Water Extraction and Water Addition.] Weizenvorbereitung. Theorie und Praxis.--Ausländisches und inländisches Getreide vorbereiten.--Wasserentzug und Wassereinbringung. Mühle 69(52): 1,357 (Dec. 29, 1932).

Y. 664
[Hulling and Conditioning of Grain. The Effect of the Color Layer and Outer Bran Particles on the Flour.] Enthülsen und Vorbereiten von Getreide. Die Wirkung von Farbstoffschicht und Schalenteilchen auf das Mehl. Mühle 69(49): 1,271-1,272 (Dec. 8, 1932).

Zamboni, Franco. 665
[The Importance of the Relative Humidity of the Air in Grain Conditioning.] L'importanza dell'umidità relativa dell'aria nel condizionamento del grano. Selezione di Tec. Molitoria 7(12): 77-80 (Dec. 1956).

Ziegler, E. 666
[Influence of Conditioning on the Extensibility of Wheat Dough.] Einfluss der Konditionierung auf die Dehnbarkeit des Weizenteiges. Mühle 72(33): 1,035-1,038 (1935).

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